PUERTO RICO EXPERIMENT STATION
of the
UNITED STATES DEPARTMENT OF AGRICULTURE
MAYAGUEZ, PUERTO RICO

REPORT OF THE PUERTO RICO EXPERIMENT STATION 1936

Issued August 1937

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PUERTO RICO EXPERIMENT STATION

Administered by the Office of Experiment Stations, United States Department of Agriculture

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CONTENTS

INTRODUCTION

In the last annual report of this experiment station the relationship of population to agricultural problems was emphasized; data were presented showing that with 501 people per square mile, with but seven-tenths of an acre of arable land per person and a very large proportion of the income of the island dependent upon agriculture, crops of high value per acre seemed essential for a reasonable standard of living for both the agricultural and the urban population of Puerto Rico.

It was pointed out that in many cases the topsoils of the island, which contain the largest concentrations of plant nutrients, have been washed away by soil erosion which has been more severe in Puerto Rico than in many continental areas, due to its steep hillsides and the intense tropical rains. The use of bench terraces to check erosion and increase areas of arable land was described; such terraces are shown in figure 1. With soils depleted by erosion and little or no mineral resources, one of the outstanding assets of the island is its climate, with 12 months of weather favorable to almost maximum growing conditions and complete absence of frost. A method of

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FIGURE 1.—Contour bench terraces constructed at the experiment station during the year; the slope is 45 feet per 100. Each bench is constructed to slope inward where a small canal, having a drop of 3 inches per 100 feet, leads the water at slow velocity to discharge ditches. The benches not only have controlled soil erosion but also increased the area of arable land; the cost of the work necessitates their being used for crops of high value per acre.

capitalizing on this asset was indicated in the production of winter vegetables for the northern markets of the continental United States; such winter vegetables are capable of yielding high values per acre.

The occurrence of nine serious hurricanes in 110 years was mentioned, indicating the degree to which hurricane liability should be considered; the relatively small loss from hurricanes to quick-growing truck crops as compared to permanent orchard crops, was discussed.

The utilization of favorable temperatures for plant growth during the winter months at the station for accelerating the breeding programs of such crops as corn and sweetpotatoes in the continental United States was outlined.

An understanding of the foregoing viewpoints, developed in the annual report for 1935, is necessary for the consideration of the lines of activity which were pursued in the fiscal year ended June 30, 1936.

RELATION OF POPULATION TO LAND UTILIZATION IN PUERTO RICO

Dependence of island welfare upon agriculture is emphasized by census figures.

The importance of agriculture to Puerto Rico is emphasized by figures of the United States Bureau of the Census; a knowledge of such census figures and their significance is essential for an intimate understanding of the problems of land utilization in the island. In table 1 are presented data showing the nature of employment of the gainful workers in the island as recorded in the census of 1930.

TABLE 1.—*Occupations of all gainfully employed population in Puerto Rico in 1930, indicating the large proportion of such workers engaged in agriculture*

Occupation	Total employed	Portion of total gainfully employed	Occupation	Total employed	Portion of total gainfully employed
	Number	*Percent*	Manufacturing and mechanical—Continued.	*Number*	*Percent*
Agriculture	262,623	52.1	Other manufacturing and mechanical	22,542	4.5
Farm laborers	209,902	41.7	Transportation	17,137	3.4
Tenants, owners, managers	52,721	10.5	Trade	40,346	8.0
Forestry and fishing	954	.2	Professional	12,311	2.4
Extraction of minerals	364	.1	Domestic and personal	48,243	9.6
Manufacturing and mechanical	111,319	22.2	Not specified	3,456	.8
Building	12,760	2.6	Public service	7,052	1.4
Cigar and tobacco	15,508	3.1			
Food and allied	15,606	3.1	Total	503,805	100.0
Hand trades	44,903	8.9			

Fifty-two percent of workers were directly employed in agriculture in 1930.

In 1930 agriculture alone supplied direct employment for 52 percent of the gainfully employed workers of the island, or more than all other occupations combined. Consideration should be given to the fact that these figures show direct employment in agriculture; there are no figures to show the indirect employment due to agricultural production, such as in processing agricultural products, shipping, and furnishing of supplies.

The figures in table 1 indicate that 41.7 percent of all employment, or 80 percent of the agricultural employment, was the farm-labor type whose earnings varied from 40 cents to $1 per day and whose period of employment in some cases has been but 5 to 6 months per year. These employment and wage figures are also fundamental for any consideration of new industries projected for development in the island.

Seventy-nine percent of all exports in 1934 and 1935 were directly derived from agriculture.

Another series of figures presented in table 2 shows perhaps in greater detail the part which agricultural products play in the income of the island. It can be seen that in the fiscal years 1934 and 1935, 79 percent of all exports of the island were articles of agricultural origin.

TABLE 2.—*Exports of agricultural origin compared with nonagricultural exports from Puerto Rico, with values, for the fiscal years 1934 and 1935* [1]

Articles of export	1934		1935	
	To continental United States	To foreign countries	To continental United States	To foreign countries
Agricultural products:				
Sugar, raw, refined, and molasses	$55,165,172	$5,250	$50,491,035	$381
Tobacco, leaf, stems, cigars, cigarettes, and other manufactures	7,820,203	44,178	8,487,753	18,814
Grapefruit, fresh and canned, oranges, and citron	1,196,781	138,989	555,104	6,862
Pineapples, fresh	1,029,159	27,514	911,219	
Other fresh and prepared fruits	305,413	54,219	621,232	49,556
Animal products	89,143	329,443	71,522	153,246
Grains and fodders		119,080		109,001
Vegetables, fresh and others	151,053	44,653	189,776	29,344
Coconuts	171,259		232,782	
Coffee	646,813	25,061	195,186	12,622
Cocoa beans and chocolate	6,846	4,187	10,367	1,915
Alcohol	316,954		322,769	
Raw cotton				6,738
Other agricultural products	108,043	60,821	139,817	48,207
Total	67,006,839	853,395	62,228,562	436,686
Total agricultural products	67,860,234		62,665,248	
Nonagricultural exports:				
Industrial products	212,942	1,470,299	179,850	1,217,756
Wood and manufactures of	1,908	99,357	1,522	98,726
Mineral products	80,900		110,877	
Manufactures of noncotton textile products	1,577,081	53,926	1,374,091	66,785
Hats and other palm-leaf or straw products	417,028	21,009	303,332	51,676
Manufactures of cotton textiles	13,196,034	259,515	13,041,221	203,864
Total	15,485,893	1,904,106	15,010,893	1,638,807
Total nonagricultural products	17,389,999		16,649,700	
Total all exports	85,250,233		79,314,948	
Agricultural products—percent	79.6		79.0	

[1] Figures are compiled from Puerto Rico Trade issued by the National City Bank of New York.

From the data presented in tables 1 and 2, it is impressively evident that agriculture, in recent years at least, has been the chief employer of labor and chief source of income for the island.

Areas of arable land in the island decreased 22 percent in 20-year period.

In view of the fact that agriculture is the basic industry in Puerto Rico, it is important to note that the areas of arable land in the island have decreased during the last 20 years.

The areas classed by the Bureau of the Census as improved and unimproved land in the years 1910, 1920, and 1930 are shown in table 3.

TABLE 3.—*Areas of farm land, classified as improved or unimproved, in stated years* [1]

Classified land	1910		1920		1930		Change in acreage from 1910 to 1930
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Percent*
Improved	1,570,304	75.3	1,303,547	64.5	1,222,284	61.7	−22.2
Woodland	291,908	14.0	296,213	14.6	322,447	16.3	+10.5
Unimproved	222,950	10.7	422,644	20.9	434,743	22.0	+95.0
Total	2,085,162		2,022,404		1,979,474		−5.1

[1] Bureau of the Census.

Three important factors in the decrease of arable land have been: The world overproduction of coffee with resulting lower prices; the hurricane of 1928; and possibly of even greater importance than either of the preceding, the severe sheet erosion resulting from intense, heavy rains on the steep hillsides, cultivated with no precautionary measures to prevent the loss of the more fertile topsoils richer in plant nutrients, essential for profitable crop production.

Urban population has increased twice as fast as rural population.

Table 4 shows the comparative increase in urban and rural population from 1900 to 1930.

TABLE 4.—*Increase of population in urban as compared with rural areas, 1900 to 1930*

Class	1900		1910		1920		1930		Increase, 1900 to 1930
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Percent*
Urban	138,703	14.6	224,620	20.1	283,934	21.8	427,221	27.7	208.0
Rural	814,540	85.4	893,392	79.9	1,015,875	78.2	1,116,692	72.3	37.1
Total	953,243		1,118,012		1,299,809		1,543,913		62.0

The table shows that in the period from 1900 to 1930, the urban population has increased 208 percent as compared to but 37 percent for the rural population. Thus it is apparent that in this island depending principally upon agriculture for its income the population is shifting from the rural areas to the cities, and the areas of arable land that are the principal source of income have not been increased, but have decreased more than 20 percent.

Increase of population is accentuating land-utilization problems.

Further analysis was made to compare the birth rate of the island with similar figures from other countries. Data are presented in

figure 2 giving birth rates for the years 1915–34 for representative countries in comparison with Puerto Rico.[1]

It is obvious that Puerto Rico has a relatively high birth rate as compared to other countries, a condition that emphasizes the increasingly acute problem of land scarcity.

Population increases have been due principally to natural causes.

In addition to increases in population due to excess of births over deaths, there is the factor of immigration to be considered. The data in table 5 were obtained from the Fifteenth Census of the United

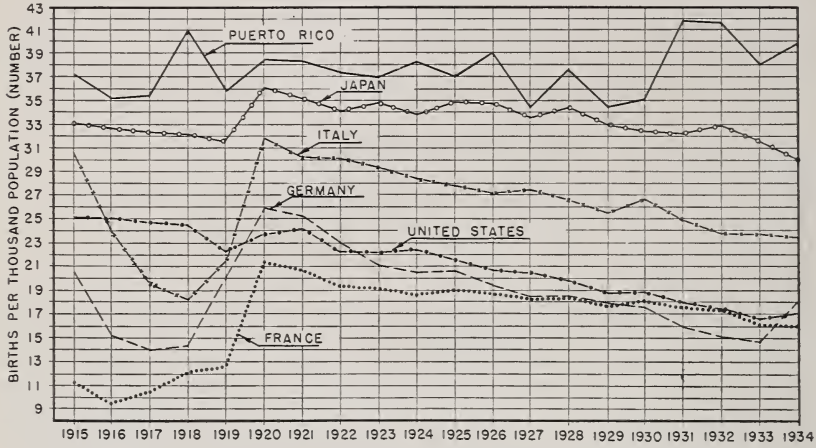

FIGURE 2.—Births per 1,000 population in Puerto Rico and representative countries, 1915–34.

States, from the Bureau of Epidemiology and Vital Statistics of the Insular Department of Health, and from preliminary releases of 1935 population by the Puerto Rico Reconstruction Administration.

TABLE 5.—*A comparison of the factors of natural increase and immigration as causes of population increase in Puerto Rico*

Period	Population at start of period	Net natural increase	Net immigration	Increase in population due to—	
				Natural increase	Net immigration
				Percent	*Percent*
1899–1910	953,243	68,004	96,765	41.3	58.7
1910–20	1,118,012	159,665	22,132	87.8	12.2
1920–30	1,299,809	217,296	26,808	89.0	11.0
1930–35	1,543,913	159,993	19,088	89.3	10.7

It is clear from table 5 that net immigration during the decade following American occupation was more important than natural increases; the phenomenon of such heavy immigration between 1899 and 1910 raises some interesting conjectures, it being said that there were many immigrations from Cuba, the island of Hispaniola (Santo

[1] The data upon which the graph is based were obtained through the kindness of W. L. Austin, Director, U. S. Bureau of the Census.

Domingo), and Venezuela at this time. For the last 25 years, however, natural increase has accounted for an average of 88 percent of the observed increase in population while immigration has been a decreasing factor.

Since natural increases in population are due to excess of births over deaths, the analysis of population would not be complete without considering the death rate of the population. In figure 3 is presented the curve for the death rate of Puerto Rico compared with similar curves of representative countries for the years 1915 to 1934.[2] Figure 3 reveals that the island has a relatively high death rate when compared to other representative countries, but that the death rate has made an irregular decline in the last 20 years. The increase in rate of growth of population has been due fully as much to decreases in death rate as to increases in birth rate.

Although it is impossible to predict the course of birth-rate figures, it seems reasonable to expect that the relatively high death rate can

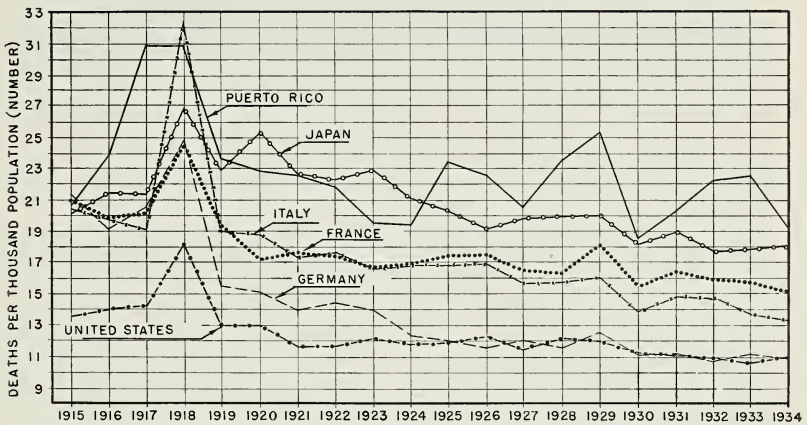

FIGURE 3.—Deaths per 1,000 population in Puerto Rico and representative countries, 1915–34.

be further decreased by sanitation and educational measures already undertaken by the Federal and Insular Governments. Thus, it would not be unreasonable to expect the net increase in population to be augmented at an increasing rate until the death rate becomes stabilized, and that consequently an increasing pressure will be placed upon the present areas of arable land to provide income for the population.

Birth rate has doubled and death rate halved since year 1900.

In figure 4 are presented data showing a comparison of the birth and death rates for Puerto Rico for each year from 1900 to 1935. In 1900, the only year in which the death rate has exceeded the birth rate, nearly twice as many persons died as were born. From 1901 to 1935 the birth rate has exceeded the death rate by increasing amounts. Since 1900 there has been an irregular lowering of the death rate from more than 36 to less than 19 per thousand in 1935. During the same period births have increased from 20 to 40 per thousand. The area

[2] The data upon which the graph is based were obtained through the kindness of W L. Austin, Director, U. S. Bureau of the Census.

between the curves, shown by cross hatching, represents the net gain of population per year per thousand inhabitants. The irregular but persistent increase in this area in recent years is apparent.

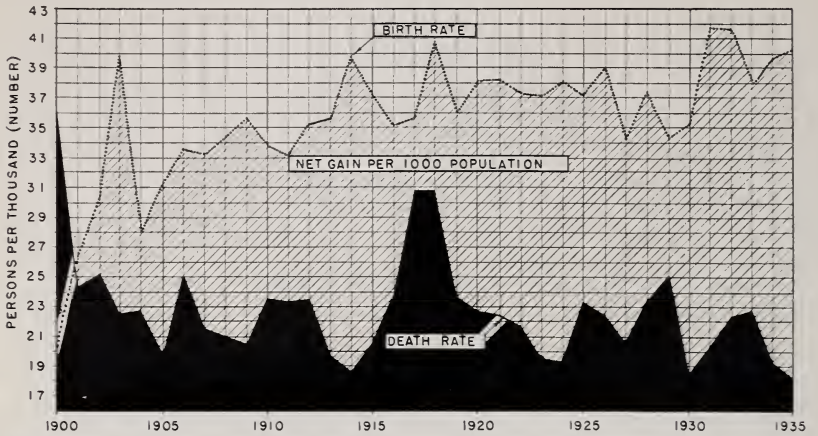

FIGURE 4.—A comparison of birth and death rates for Puerto Rico, 1900–1935, based on figures from the Insular Bureau of Epidemiology and Vital Statistics.

Increase of population and decrease of arable land directly affect nature of agriculture.

Data on arable land supplied by the census have been combined with figures on birth rates obtained through the cooperation of the

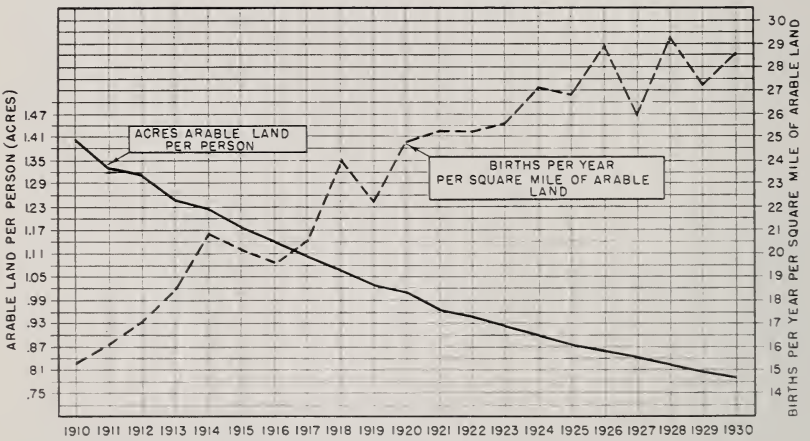

FIGURE 5.—Acres of arable land available per person compared with number of births per square mile of arable land in Puerto Rico, 1910–30.

Insular Bureau of Epidemiology and Vital Statistics and the data are presented in figure 5. Arable-land acreage for years between census periods has been calculated by apportioning the change in acreage recorded at succeeding decennial census dates equally among the 9 intervening years. The number of births per year per square mile of arable land has increased rapidly in the 20 years from 1910 to 1930. This, together with the decrease in death rate, has been the principal factor in the decline in the area of arable land per person.

Figure 5 substantiates the conclusion presented in the annual report of last year that only crops of high value per acre should be produced in Puerto Rico. A second conclusion seems evident, that not only is the production of crops of high value per acre essential, but that with a continuing increase in population the total values of crops per acre must also progress by proportionate amounts if even the present standards of living are to be maintained. A third conclusion would seem obvious, that new crops which may be developed should lend themselves to processing in the island, relieving the limited land areas to some extent from the maintenance of such a large proportion of the crowded population.

The need for studying methods for converting nonarable land into productive areas, not only by drainage and irrigation, but by soil-erosion control, soil rehabilitation, and the adaptation of new crops to areas at present considered nonarable is apparent.

Census figures for 1930 show 434,743 acres of unimproved land in the island; this area constitutes more than 33 percent of the present arable area, and its utilization would result in 0.95 acre of land per person rather than 0.70 as at present.

The studies of population in relation to land utilization have been the work of Alfred N. Watson, biometrician and plant physiologist, and Atherton Lee, director of the station.

CLIMATIC AND MARKETING FACTORS IN RELATION TO LAND UTILIZATION

Puerto Rico with small land area has widely diversified climate.

Puerto Rico with 3,435 square miles in its area, at its widest point is but 40 miles from north to south; in length, it is approximately 112 miles from the point farthest east to the point farthest west. Its size may be best visualized by comparing it with the State of Connecticut, which is 4,965 square miles in area. Yet in the comparatively small area of Puerto Rico there are considerable diversities of climate because of great differences in amounts and distribution of rainfall. At Luquillo in the northeastern mountains an annual rainfall of more than 150 inches has been recorded and a dense tropical vegetation predominates, while less than 40 miles to the southwest Aguirre has an average annual rainfall of but 38 inches, and cactus and other dry-land plants are noticeable in the native vegetation. The driest part of the island is at the southwestern end where an average annual rainfall of less than 30 inches occurs, and fields of cactus and semiarid conditions prevail; yet but 24 miles away at Maricao the rainfall has averaged 111 inches per year during the last 20 years.

Strong steady trade winds are a factor to be considered in some districts.

In the northeast, of which Luquillo is representative, continuous northeast and easterly trade winds of from 15 to 30 miles per hour persist at times for days. In contrast in the western end of the island, protected by a high mountain range, winds are much reduced and air movements are for the most part of local origin. The Isabela district in the northwestern part of the island has no wind protection to the northeast and is exposed to the continuous prevailing trade winds. Even in the mountainous districts in the center of the island,

there are localities where the strong trade winds persist without being tempered. The presence or absence of winds is an important factor contributing to success or difficulty in the growing of a number of crops. In addition to rainfall and prevalence of winds, other important and obvious factors are the character of soils, topography, nearness to shipping points, and availability of cold-storage facilities.

Small area of land per individual emphasizes necessity of constant cropping.

In the progressive cane-sugar-producing countries, yields of sugar are not only recorded as yields of sugar per acre, but also as yields of sugar per acre per month; this has resulted from the development that sugar can often be more profitably grown for 15 or 18 months than as an annual crop for 12 months. The figure, yields of sugar per acre per month, seems to give a much better index of the efficiency with which the land is employed than the figure for yields of sugar per acre, as usually calculated, per crop.

Each day land is idle annual income of island is decreased.

Considered from this viewpoint there sometimes appears to be a lack of appreciation of the time element as an important factor in the production of other crops. This island, having 365 days each year in which the temperatures are favorable for crop production, apparently is in a position to increase its agricultural production and income by a closer consideration of the time element in crop production; in other words, it would appear logical to systematize cropping, so that after the harvesting of one crop, tillage and planting could advantageously follow immediately provided a crop suitable for the changing seasonal conditions has been selected.

The conception that each field should be producing each day of the year is highly important because of crowded land conditions, and is more applicable in the continuous growing temperatures of the Tropics than in temperate countries of nonproductive winters, more capable of skillful maneuvering with short truck and field crops than with permanent orchard crops.

SOME CROP ADAPTATIONS FOR THE MOUNTAINOUS AREAS OF THE ISLAND

New crops can increase areas of productive land.

According to the 1930 census, but 57 percent of the total area of Puerto Rico is arable, while 43 percent is classed as nonarable. A large proportion of the area classed as nonarable consists of steep hillsides subject to tropical downpours; even if the topography permitted tillage, the loosening of the soils in plowing and cultivation would appear highly wasteful from the standpoint of soil conservation and loss of plant nutrients.

Bamboos are adapted to cultivation on steep hillsides and will increase productive areas.

In years past the station has introduced nine species of bamboo which have developed to sufficient extent that some distribution of small plants has been possible during the year; several of these older established species have shown themselves highly valuable for furniture manufacture and other fabrication purposes. During the last 2 years it has been possible to introduce 19 additional bamboo species, some of which will apparently also be valuable.

Bamboos resist erosion and hurricanes.

Bamboos, because of their matted roots, have shown that they are among the best tropical plants for preventing soil erosion. Bamboos also need little or no cultivation other than the removal of vines competing for light during the early stages of growth; their harvesting does not stir or loosen the soil. Bamboo production, therefore, appears logical on some of the steep hillsides. Experience in severe hurricanes has shown that bamboos are also resistant to winds of high velocity. Apparently the extension of areas planted to bamboo can reclaim and make productive considerable areas of land previously classed as nonarable.

The experience of the station would indicate that bamboo production is not economic for high-valued flat lands unless used for windbreaks, nor for lands with less than an annual average rainfall of 40 or 50 inches.

Manufactured bamboo has favorable protective tariff.

There is no import tax on unmanufactured bamboo from foreign countries. However, on bamboo furniture manufactures, the tariff is 60 percent ad valorem; there has been great interest in such manufactures in the experimental shop at the station. The evidence to date indicates that there is a greater demand for these bamboo articles than can be filled at the present time. Bamboo is an agricultural crop that would lend itself to fabrication or industrialization, thus creating the maximum of employment.

Palm chestnuts can also be produced on steep hillsides.

Another crop, although not so well adapted to check soil erosion as bamboo, which, however, requires little or no tillage, cultivation, or loosening of the soil in harvesting, exists in the palm chestnut, *Guilielma utilis*. This is the palm introduced from Honduras in 1922, which was mentioned in the annual report for 1935. It yields seeds of a size and flavor similar to large chestnuts. These seeds are also very high in starch and contain some oils and small concentrations of proteins. The planting of this palm chestnut on our steep hillsides could make some of the slopes that are now classed as waste lands at least somewhat more productive than they are at present, and thus reduce the large proportion of nonproductive land in the island.

Vanilla adapted to production in humid parts of island having little air movement.

The commercial vanilla, *Vanilla fragrans*, is a member of the family Orchidaceae and, in common with many other orchids, is adapted to a humid environment in which there are no strong winds; such environmental conditions occur in western Puerto Rico. Considered from the viewpoint of regional planning, and the utilization of natural environment to secure the maximum returns from our lands and crops, the western part of Puerto Rico is better suited for vanilla production than other parts of the island, for there is less wind movement there, and the moisture conditions during the growing season for vanilla are usually uniform and favorable. This crop requires a short period of dry weather for pollination, harvesting, and processing; such a short dry season exists on the western slopes of Puerto Rico. Existing plantings of vanilla in the western end of the island have shown thrift and vigor indicating that the environmental factors are favorable for this crop.

Cured vanilla beans from foreign countries, according to the Tariff Act of 1930, and as modified by the reciprocity treaty of 1936 with France, are subject to an import duty of 15 cents per pound which vanilla from Puerto Rico is not required to pay.

Vanilla is a crop of high value per acre suitable for hillside bench-terrace cultivation.

Vanilla production has been shown during the year to be well adapted to cultivation by terracing on some of the steep hillsides of the western part. It is a crop on which the ratio of shipping charges to total value is very small and thus is also well adapted to our somewhat inaccessible mountainous areas. The returns from vanilla beans at prevailing prices have been much higher than from coffee, a crop which vanilla might profitably displace from some small areas on the western slopes of the island; at prices prevailing during the last few years, it would be considered as returning an income that compares favorably with the results from sugarcane production. Vanilla cultivation at the station has also put to use lands which were unproductive or occupied by crops of low value per acre. This crop is one which employs much labor and can provide profitable work for some of the unemployed.

Land and labor are more expensive in Puerto Rico than in many other coffee-producing countries.

It was pointed out in the annual report for last year that many of the countries where large proportions of the world's supply of coffee are produced are within that part of the Tropics which are not commonly subject to losses from hurricanes. The effort to produce coffee in Puerto Rico starts with a handicap of hurricane liability to which some of the competing countries are not subject. Land areas are more extensive and land values are much cheaper in most other coffee-producing countries. The standards of living and rates of payment for agricultural labor are also much lower. Coffee may enter the continental United States from foreign countries without the payment of any import tax, hence coffee from this island has no advantage in world competition.

NORTH COAST OF ISLAND HAS TRANSPORTATION AND CLIMATIC ADVANTAGES FOR SOME CROPS

Truck crops for winter marketing in New York yield high annual values per acre.

In the previous annual report the production of truck crops for winter marketing in the continental United States was pointed out as one of the most direct ways of capitalizing on Puerto Rico's greatest asset, its 12 months of growing temperatures with no danger of frost. Such truck crops vary considerably in their environmental requirements. However, other than climatic conditions a limiting factor exists in the availability of refrigeration space on steamship lines. At the present time ships with refrigeration space for freight call only at San Juan. Thus it would appear logical that truck crops for winter marketing on the continent would be marketed for the present most economically from areas within trucking distance of San Juan.

The lighter more sandy soils of the farming areas of the north coast within ready shipping distances of San Juan are more favorable to many truck crops than the heavier soils in the interior or on the western end of Puerto Rico. In this northern district the rainfall distribution is also more favorable, while records and experience both show that the eastern and western areas of the island are too wet during much of the year for economical truck-crop production.

Pineapples are high-value crop resistant to hurricanes.

In the search for crops that will give returns of high value per acre, that are well adapted to the island soils and climate, and that are not damaged by hurricanes, pineapples for marketing fresh in the continental United States fill most of these requirements. Pineapples have shown themselves well adapted to the soils and degree of rainfall along much of the northern coast between Fajardo on the east and Arecibo on the west. Refrigeration is not necessary in shipping this crop, although in the last few years possibly from 5 to 10 percent of the crop at stages near maturity have been shipped under refrigeration. The returns per acre from the production of fresh pineapples have been good and compare favorably with the average income per acre per month from sugarcane at present prices. In the last few years there has been some distribution of canned pineapples from Puerto Rico which gives to growers come certainty as to an outlet for small surpluses. The pineapple crop is also advantageous to the island because a large proportion of its cost of production is expended for field labor.

The possibilities of overproduction of fresh pineapples lead to the suggestion that this crop should not be expanded beyond the areas in which it is well adapted to environmental factors such as soils and rainfall or beyond accessibility to shipping facilities.

Mangoes enjoy favorable protective tariff.

Mango trees have been successfully grown for years. The large majority of existing mature trees throughout the island are of the so-called native varieties which, however, are probably all of foreign origin, inasmuch as the species *Mangifera indica* apparently is indigenous to southern Asia or the East Indies. Fruits of these so-called native Puerto Rican varieties are in general rather small and have a high proportion of fiber and apparently would not be suited for marketing in the continental United States.

The Tariff Act of 1930 placed a tax of 15 cents per pound on the importation of mangoes from foreign countries. Thus Puerto Rico, with free entry of its products into the continental United States, is in a favorable position, as compared with other tropical American countries, to produce mangoes of the better varieties which have an active consumer demand.

During the last 30 years the station has assembled a collection of 59 varieties of mangoes from all parts of the Tropics which is said to be the largest and most representative in the world. Among them there are possibly 10 or 12 with little or no fiber, a large proportion of edible pulp to volume and weight of seed, and with distinctive flavors making their successful marketing a good probability. Metropolitan bakers have shown interest in an adequate supply of mangoes for their industry.

Various processing methods will kill fruitfly larvae in mangoes.

The mango has several pests that handicap production, of which two have been observed to be serious; one is an insect pest, the other a fungus disease. The insect, known as the West Indian fruitfly, *Anastrepha* sp., has been much more serious in infesting fruits of some varieties than others. In the station collection some of the most desirable varieties, from the standpoint of desirable flavor and absence of fiber, have been found to possess a considerable degree of resistance to the fruitfly. The heaviest infestation has occurred when the fruit was tree-ripe, and harvesting 1 or 2 weeks before the fruit reached such a degree of maturity has avoided considerable infestation.

Under the plant-quarantine regulations of the Department of Agriculture, the entry of fresh mangoes, among other host fruits, into the continental United States from Puerto Rico, is prohibited because of the presence of fruitflies. However, mangoes may be canned, dried, or frozen so as to kill such occasional larvae of the fruitfly as might be present; thus the introduction of this insect pest of fruit crops would be prevented. A major project carried on by the Bureau of Entomology and Plant Quarantine during the past year was designed to determine the possibilities of killing the immature stages of fruitflies in fresh fruit by low temperatures above freezing and by vapor heat.

Mangoes avoid serious fungus diseases in dry sections of island.

Leaves, twigs, and fruits of mango trees are subject to a fungus disease known as anthracnose which is favored by wet, humid weather. In the collection of varieties at the station, several of the best varieties have shown themselves to be resistant to anthracnose. However, even some of the more susceptible varieties have been grown in the drier districts of the south coast, and in such less humid environment have successfully avoided severe infection with anthracnose. Thus the best utilization of environmental factors indicates that mango production can best be attemped in the drier regions of the foothills of the southern coast or in some of the drier parts of the north coast.

Most mango varieties possess high vegetative vigor. Although the trees present a great bulk to hurricane winds of high velocity, experience in the East Indies has shown that even when blown over they seldom die. Logical regional planning would seem to indicate that mangoes could more safely be grown in some of our steep-sided valleys where they may attain some degree of protection from hurricane winds.

Producers' cooperatives seem important for such new crops.

The profitable production of truck crops for winter marketing is dependent upon the most competent technical knowledge for field management as well as alert representation in the continental markets. The production of other crops has shown the necessity of increased technical knowledge. The small producers of Puerto Rico individually have not been in a position to have market representation or obtain through experience the technical knowledge necessary for successful truck-crop or other specialized production. In this situation it would seem essential to form cooperative associations in which technical men would be employed to guide production methods, packing, and shipping, as well as provide expert market representation.

Regional specialization aids dissemination of technical information and formation of cooperatives.

There is some evidence and experience to indicate that once an environment has been found favorable to a given crop, specialization of such a district in that crop will best promote its success. The advantages of crop diversification have been outlined repeatedly in farm literature, but against wide diversification is the feature that success with many crops depends upon specialized technical information. The consideration of regional specialization in crops is important, not only because such specialization will lend itself to the better dissemination of technical knowledge in a community alert to all methods of progress in that crop but also because of the greater facility with which cooperatives for a specialized crop may be formed.

Heavy parasite infestations minimize areas available for animal industry.

Studies by Department of Agriculture parasitologists have shown that in the humid regions of the island, conditions are favorable for mass infections with intestinal parasites of many farm animals. The severity of these conditions has resulted in recommendations that the animal industries should be confined to the more arid sections. It would, therefore, seem desirable for regional planning to take into consideration this factor of heavy infestations of animal parasites in the humid sections.

Pastures yield small returns per acre.

In the continental United States a considerable trend exists to remove land from crop production and place it in pastures and soil-improving crops, chiefly for the purpose of aiding soil conservation. There exists some tendency to carry this trend into the agricultural program of Puerto Rico, which, however, seems uneconomic. Puerto Rico, with but 0.7 acre of arable land per person, apparently cannot afford to devote a larger proportion of its land area to the production of such low-value-per-acre crops as pasture grasses and there are even areas now in pasture which could possibly be more logically used for more remunerative crops.

Many steep slopes devoted to pasture are overgrazed, and the heavy tropical rains produce erosion in such lands, perhaps less serious than that in tilled soils, but severe nevertheless. Figures 6 and 7 show some of the grassed pasture lands where erosion is progressing and which are not of uncommon occurrence. The extension of land areas into pasture, therefore, would seem to require considerable deliberation and study, not only as regards most profitable utilization of land but also from the standpoint of soil conservation and to avoid misplaced investments where heavy parasitic infestations may result in losses instead of income.

Choice of crop may convert climatic liability to asset.

The climate of Puerto Rico is so diverse because of the varied rainfall, that in one municipality a crop may be growing successfully while in another municipality, possibly but 15 or 20 miles away, severe handicaps are encountered in attempting to grow the same crop. Crop plants of the Tropics are so numerous and have such diverse requirements as regards moisture and other environmental factors

that a climate unfavorable for one crop may be found a distinct asset for another. To obtain the greatest returns from the limited land of the island the adaptation of the crop plant to climatic and soil factors can be logically studied in considerable detail; such adaptation of

FIGURE 6.—Erosion of various types in sloping lands of overgrazed pastures at Sabana Grande, 1936.

crops to their proper environment can save a grower much unnecessary labor and investment, as well as rendering a whole municipality or district prosperous. The study of environmental factors in relation to new crops would seem to be an essential for profitable agriculture and in turn to economic reconstruction.

PREVENTION OF SOIL EROSION IS ESSENTIAL FOR ISLAND RECONSTRUCTION

Island soils have been depleted of essential plant nutrients.

It is a rather common misconception of visitors to the Tropics from temperate countries that all tropical soils are rich and fertile. Puerto Rico has had an unfortunate history in this regard, for in comparison with other tropical countries many areas of its soils are not fertile.

The rainfall of most parts of Puerto Rico is considerably greater than the rainfall in such neighboring islands as Hispaniola and Cuba. In parts of both of these other islands the mountains are much higher than the highest elevations in Puerto Rico, yet the proportion of

FIGURE 7.—Both sheet and gully erosion in severe form in an overgrazed pasture at Sabana Grande

mountainous country with high rainfall to lowland areas with moderate rainfall is much less in those islands than in Puerto Rico. Puerto Rico has a large proportion of its area in mountains which precipitate moisture from the northeast trade winds resulting in comparatively high average annual rates of rainfall and in many cases in precipitation of great intensity. Moreover, the extensive mountainous areas consist largely of steep hillsides from which it is very easy for the soil to be eroded.

Dense population has increased erosion.

In addition to heavier rainfall and greater proportion of area in steep slopes, a third factor contributing to the extent of soil erosion in Puerto Rico is a much greater density of population as compared with that in the neighboring islands. The crowded population has resulted in attempts in past years to place under cultivation some of these steep hillsides, subject to intense rains. The loosening of the soil in

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plowing, cultivation, weeding, and harvesting operations on such steep slopes has produced sheet erosion, and this in turn has caused the loss of a large proportion of the surface soils which contain the greatest concentrations of plant nutrients. As a result, therefore, much of the surface soil on the steep slopes has lost a high proportion of plant nutrients for crop production, and such soils are unfertile and comparatively unproductive until the nutrients have been restored.

Land scarcity necessitates land use while erosion is prevented and soils rehabilitated.

In achieving soil conservation, not only is it necessary that soil erosion be checked but it is essential that the ravages resulting from erosion in past years be repaired and the nutrient supplies in the soils necessary for crop production coincidently built up; the land must meanwhile maintain the livelihood of the agriculturist. The soil-conservation problems indicated are not only urgent but are intriguing to the agricultural technologist.

Various types of experimental terraces have been constructed.

In the preliminary studies of the engineering phases of soil-erosion control that have been carried on under Puerto Rican conditions it is possible to record some progress during the year. On the lateritic soils of the Las Mesas property of the station approximately 1 mile of mangum terraces have been constructed with ox-drawn plows and hand labor. These mangum terraces have been highly successful in fields having moderate slopes with a fall of 18 percent or less. A cross section showing this type of terrace as constructed at Las Mesas is shown in figure 8*A*.

In the areas of steeper slopes several acres of experimental bench terraces have been constructed. In one field, with a slope of 45 percent, such bench terraces have been in service for 9 months, and from an area of more than 2 acres not more than 800 pounds of soil have been lost; during this period frequent intense rains have been recorded, in one instance 2.15 inches having fallen in 1 hour.

In constructing these bench terraces to avoid the passage of water over their edges, each bench was sloped to drain the water from its outer edge to its inner part cut into the slope. Figure 8*B* shows a cross section of such bench terraces showing the inward slope of the bench, and the slope of the inner wall of the cut and angle of repose of fill. The bench terraces were laid out to allow a lateral fall of 3 to 6 inches per 100 feet, sufficient to permit accumulated water to flow along the inner margin of the bench without cutting the soil. This slight lateral sloping along the contours was constructed to lead the water in the direction of the upper part of the valley. In this way vertical discharge ditches were avoided which would discharge run-off water with high velocity and consequent severe erosion, and instead the run-off water from the bench terraces eventually drained onto the floor of the valley at its upper limits.

These bench terraces were constructed mainly by hand labor, and on similar slopes of 45 percent a minimum cost on private properties would possibly be $50 or $60 per acre. Such terraces logically, therefore, would have to be devoted to crops of high value per acre in order to justify such an expenditure. Because the steep hillsides on which

the terraces would be constructed usually occur in small steep-sided valleys, they afford some degree of protection to crops against hurricane winds.

One of the areas of 3 acres devoted to bench terraces is shown in figure 1.

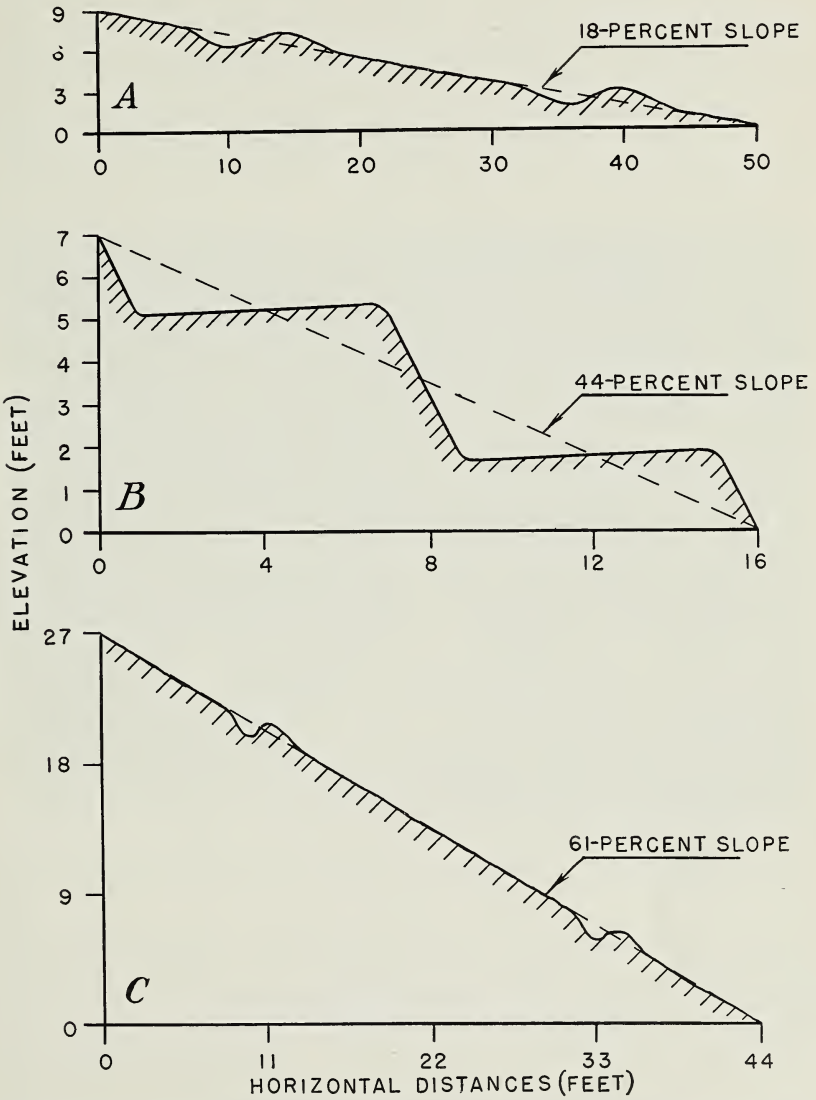

FIGURE 8.—Three types of terraces constructed at the experiment station during the year: *A*, Cross section of a mangum terrace which functioned well on moderate slopes; *B*, cross section of bench terrace, for steeper slopes; *C*, cross section of hillside canal, to lessen volume and velocity of run-off water on slopes too steep for terracing or crops dependent on occasional plowing or stirring of the soil.

Bench terraces increase area of arable land.

The use of bench terraces not only checks soil erosion but increases the acreage of arable land and is therefore economically advantageous to the island as a whole. Large areas of unproductive land now exist

valued at $15 to $20 an acre. The use of surplus, unemployed labor in terrace construction renders these lands capable of crop production and the financial returns justify the expenditure. It has been shown that the construction of bench terraces on steep hillsides, even in the small areas tested out at the station, transforms unemployed labor into capital wealth.

The degree of slope that can profitably be worked for bench terraces is still to be more carefully determined. However, in conversation upon this question Walter C. Lowdermilk, assistant director of the Soil Conservation Service, presented a consideration quite distinct from the usual purely engineering viewpoints. Dr. Lowdermilk stated: "The degree of slope which can be profitably terraced depends, among other factors, to a large extent upon the density of population in the region or country being studied." Thus in the continental United States where the population per square mile is small, slopes of 45 feet per 100 would possibly be considered entirely uneconomic to develop into bench terraces. However, in Puerto Rico, with its population of 501 people per square mile and with but 0.7 acre of arable land per person, not only can slopes of 45 feet per 100 be profitably terraced, but it is possible also that even steeper slopes could be economically worked into such terraces.

Canalization more economical for coffee groves than terraces.

In addition to the two foregoing types of terraces, contour canals have been built during the year along some of the steep hillsides at the experiment station. Such contour canals seemed better adapted to some of our orchard types of crops than the terraces, particularly if the orchards were already planted and established. These canals were laid out on contour lines with a drop of 3 to 6 inches per 100 feet to divert the run-off water to the upper parts of the valleys, and thus avoid the steep grades and high velocity with which water would be delivered if carried in vertical ditches to the lower parts of valleys. The contour canals seemed well adapted to such types of crops as coffee and other orchard crops planted on steep hillside areas. A cross section of one of the newly planted orchard areas at the experiment station is shown in figure 8*C*.

Earth dam lessens freshet erosion and conserves water.

During the year an earth dam was constructed in the upper part of one of the valleys on the station property; behind this dam the run-off water of bench terraces and contour canals was accumulated. The dam will allow irrigation of one of the station lowland agricultural fields during the dry season and has also served to lessen erosion from freshets which often occur during the intense downpours in the summers in western Puerto Rico.

Since this dam has been constructed, it has become evident that a series of such dams at the headwaters of the branches of any main stream can provide the best possible automatic control of floods and at comparatively low cost. By opening the irrigation outlet of this dam to a point determined by experience, the flow of water from this particular watershed has been made almost constant throughout the rainy season. With similar dams at all headwaters of a main stream the flow in the stream could be controlled so that flood damage would be greatly reduced. At the close of the rainy season it is expected to discontinue the constant flow of water and build up a supply of water for irrigation purposes during the dry season.

Another method of utilizing these dams is in the production of fresh-water fish in the reservoirs. In south China the production of fresh-water fish in such artificial bodies of water constitutes a considerable source of food for the people. A picture of this dam and reservoir is shown in figure 9.

Agronomic approach to erosion control also essential.

Because of the small area of land per individual, crops for the prevention of soil erosion on hillsides should have in addition a direct economic value; when this is not possible these soil-holding crops should be leguminous so that while they are checking erosion they will be increasing the nitrogen content of the soil.

Experience during the year has shown that several crops will satisfy these requirements. The use of the new bamboo species, which have

FIGURE 9.—An earth dam and reservoir constructed at the experiment station during the year to provide irrigation water during the dry season, minimize freshets during the rainy season, and to be stocked with fish. The irrigation outlet is seen at the left and overflow outlet in the center of the dam.

a very considerable economic value as well as great usefulness in checking soil erosion, has already been mentioned. The pigeonpea, or, as it is known in Puerto Rico, the "gandule", *Cajanus indicus*, is a legume having root nodules with nitrogen-fixing bacteria. The beans of this plant are highly valued in the diet; they are high in both protein and carbohydrate content. The pigeonpea is not among the best of plants to check erosion, for it has but a single stem in contrast to the many stems of a bamboo clump or of our ordinary forage or pasture grasses; moreover, it must be replanted frequently, thus necessitating loosening and disturbing the soil. However, the pigeonpea can be produced without investment in fertilizers, withstands both droughts and excess moisture, and makes a crop for which there is great demand. The pigeonpea, therefore, has been used at the station to check erosion on hillsides until such time as better soil-holding, profitable crops can be found.

Good grasses are available for erosion control.

Of the grasses commonly found in Puerto Rico, *Paspalum conjugatum*, known locally as "grama", is the most common in pastures. It seems satisfactory in soils low in nutrients, and experience has shown that it will check soil erosion. However, it seems best suited for the more humid parts of the island and will not survive extended periods of drought. Another grass well suited to check erosion, and very common in pastures, is known as carpet grass, *Axonopus compressus*.

Bermuda grass, *Cynodon dactylon*, is excellent in checking soil erosion and is resistant to drought. It is not luxuriant, and its value for forage is apparently not high. Its normal environment seems to be in sandy soils of an alkaline reaction, and it persists in semiarid districts where other grasses cannot survive; in the more arid parts of Puerto Rico, Bermuda grass is consequently more valuable as a ground cover than either *Paspalum conjugatum* or *Axonopus compressus*.

Para or malojillo grass, *Panicum purpurascens*, has a high degree of vegetative vigor and produces a large tonnage per acre of green feed for farm animals. It propagates readily from cuttings and easily produces roots at the nodes lying against the ground and so is well adapted to check soil erosion. It grows best in moist places in full sunlight. At the station at least six crops of heavy tonnage of green cattle feed have been produced from one field during the year. It is a grass not only favorable for checking soil erosion, but also of economic value.

Cohitre is a good source of protein for dairy animals.

One of the interesting developments of the year has been the finding that the common weed, known locally as "cohitre", which is avidly eaten by poultry, dairy, and other farm animals, is high in proteins. Cohitre, *Commelina elegans*, is a common shade- and moisture-loving weed growing in sugarcane fields and low-lying places in pastures and woodlands. It also grows readily in the shaded areas beneath coffee trees. It produces roots from its joints and is thus adapted to check soil erosion.

An analysis by the chemistry division has shown that cohitre contains as much as 22 percent of protein substances on the dry basis and its use in feeding dairy animals lessens the necessity of importing expensive protein cattle feeds. The productivity of the island coffee districts apparently can be materially increased by extending the planting of cohitre under the coffee trees and utilizing it in feeding dairy animals and hogs.

Erythrina species check soil erosion.

Puerto Rico has two or three species of the genus *Erythrina* which, if not indigenous, have at least been long established in the island. There are in addition several introduced species. The use of all of these species is increasing to provide shade for coffee and cacao trees, and to make fence posts, hedges, and supports for vanilla vines. These *Erythrina* species, known locally by various names such as "bucar", "brucar", "bucare", and "brucare", possess a high degree of vegetative vigor, and all of the species at the station seem to be very easily propagated by cuttings. They moreover have another advantage in that analyses by the chemistry division have shown that the foliage is high in protein content.

During the past year the station personnel, in constructing bench terraces and canals, have often required wooden supports or retaining walls to hold the soil in place until the angle of repose for loose soil could be reached. By using branches of the *Erythrina* species in the construction of retaining walls, a long life for these walls may be assured, inasmuch as the *Erythrina* supports do not die and rot, but germinate, grow, and live for years. These species have the additional advantage of being leguminous, with the power of fixing atmospheric nitrogen in the soil. It is the practice at the station periodically to harvest the leaves of these *Erythrina* soil supports for feeding to the dairy animals. The various *Erythrina* species therefore seem to be valuable additions to the plants which can be used in soil-erosion control.

Ornamental plants check soil erosion.

For moist places, to some extent shaded, the waxflower, *Phaeomeria speciosa*, has economic value and also has rooting features that contribute to checking soil erosion. The waxflower is one of the ginger species, easily propagated by rhizome cuttings. The mature plants develop a dense mass of rhizomes which completely bind the nearby soil. This species was mentioned in the last report of the station as being worthy of further experimentation for shipping studies, the cut flowers being waxlike, exotic, much in demand, and apparently having good shipping qualities.

Many of the common garden ferns, of which the sword fern, *Nephrolepis exaltata*, and the Boston fern, *N. exaltata* var. *bostoniensis*, are good examples, possess the feature of having extensive, closely woven, matted roots near the soil surface. Experience at the station has shown that for shaded hillsides in gardens where ornamentation is required as well as soil retention, ferns admirably fill these requisites. The common climber, *Pothos aureus*, also will spread along the ground under trees, and, with its rooting habit at each node, makes an effective soil binder as well as an ornamental.

During the year the construction of mangum and bench terraces and orchard canals has been under the direction of George J. Burkhardt, agricultural engineer of the station. However, it is a pleasure to also acknowledge the best of cooperation during the year from the personnel of the Soil Conservation Service of the Department of Agriculture, notably George L. Crawford, in charge of research in Puerto Rico for that Service; also W. W. Pate, Miles F. Stephens, and A. T. Holman of the same Service, all of whom have contributed extensively in making available the best and most recent technical advice in connection with the foregoing preliminary studies in soil conservation. Wallace Bailey and Charles Pennington of the personnel of the station also contributed freely of their time and background of experience to develop bench and mangum terraces in a way to to be best adapted for the crops which they are studying.

VANILLA PRODUCTION AND PROCESSING STUDIES

Experiment station first undertook studies of vanilla production in 1909.

In 1909 the station introduced a number of species of *Vanilla*, among which were cuttings of the most commonly grown commercial vanilla, *V. fragrans* (*planifolia*). *Vanilla* species seem to have been grown previously in the island in a desultory way, but apparently not

commercially. In 1919 the station published Bulletin No. 26, Vanilla, a Promising New Crop for Puerto Rico. Following this, stimulated by the work of the station in this crop, several planters undertook commercial production of vanilla, and some of their plantings were notably profitable.

An indigenous vanilla species occurs in Puerto Rico.

It is of interest to note that during the past year one of the *Vanilla* species found growing in uncultivated areas and apparently indigenous to the island has been identified. Herbarium specimens of the flowers and fruits of this species were collected and submitted to Charles Schweinfurth of the Botanical Museum, Harvard University, who determined this species as *V. barbellata* Reichenbach f.

Absence of strong winds desirable for vanilla production.

Vanilla plants, in common with most orchid species, react most favorably in an environment lacking strong winds. A slow air movement caused by changes in temperature has some advantages, but winds that are too strong accelerate the evaporation from the foliage, and vegetative growth is less favorable. Another disadvantage of strong winds is that they cause the beans to rub against the supports or other parts of the vines, producing scars and blemishes that affect their appearance unfavorably and reduce their selling price.

In the western part of Puerto Rico, particularly in some of the deep steep-sided valleys, the winds are much reduced in velocity and vanilla vines develop vegetatively under conditions that seem most favorable to them.

Bench terraces for soil-erosion control are adapted to vanilla culture.

Vanilla is a crop requiring a great deal of semiskilled hand labor. At the present time it is considered a necessary practice to hand-pollinate the flowers to secure a good stand of fruits and control the size of the crop. Bench terracing not only aids in checking soil erosion but also places the semiskilled worker engaged in vanilla-flower pollination or harvesting in a most advantageous position for these delicate operations which require careful execution. Without such terraces on steep hillsides the semiskilled operator must struggle to maintain his foothold for a favorable position in which to perform these operations; without an advantageous position careful work is difficult.

The steep hillsides in themselves have some physical advantages, for not only do they afford protection from strong winds and so protect the vines from injury and the beans from blemishes, but they also favor aeration. The movement of air from the warm floors of the valleys up the hillsides develops an air movement which, while scarcely noticeable, is sufficient to bring about a condition unfavorable for the development of fungus diseases.

Erythrina species are well adapted for vanilla supports.

During the year some orientation experiments without actual yield data have been carried on with three species of *Erythrina* and *Gliricidia sepium* for use as vanilla supports. The *Erythrina* species are *E. berteroana* which is known as "dwarf bucare" or "bucare enano"; *E. poeppigiana*, which is the large bucare indigenous to Puerto Rico, so distinctive for its brilliant blossoms of a burnt-orange color; and *E. corallodendron*. These species of *Erythrina*, in addition to making

good supports, have other uses; excess leaves which are removed from the supports from time to time are high in proteins and have a material value for feed for dairy cows and other farm animals. *Gliricidia sepium* does not possess this advantage of having nutritive value. All the *Erythrina* species as well as *G. sepium* have the capacity of increasing the nitrogen content of the soil through the nitrogen-fixing bacteria in the nodules which form on the roots; this feature seems highly important to bring about the economical rehabilitation of the hillside soils of the island.

Vanilla flowers must be artificially pollinated.

In their native habitat and in their wild state, vanilla flowers are pollinated by small bees or by certain kinds of hummingbirds. In commercial plantings, however, the pollination of vanilla flowers cannot economically be left to chance, and even where pollinating insects are present, as in Mexico, artificial pollination is usually practiced. The methods of pollinating vanilla flowers are capable of wide variation, but two pollinating practices are sufficiently well established to carry distinctive names, namely the "blind method" and the "visible method." In the blind method, two petals and one sepal of the flower are held between the index and second finger of the left hand, the index finger supporting the column of the flower. By means of a small bamboo spatula about 10 centimeters long, held in the right hand, the third petal is torn from the column and the inverted stigma is raised and turned well back. With the thumb of the left hand the anther containing the pollen mass is pushed down upon the upraised surface of the stigma. Since the thumb covers the anther, the contact of the pollen with the stigma cannot be seen and for this reason the procedure is designated the "blind method."

In the visible method, the vanilla flower is held and the third petal torn away as described above for the blind method. A mass of the sticky pollen is then extracted from the anther by means of the spatula, to which the pollen adheres. With the column of the flower held between the thumb and index finger, the inverted stigma is raised sufficiently to insert the spatula containing the pollen; the pollen is then transferred by contact to the under side of the stigma. All of the processes in this method of pollination can be seen, so that it is known as the "visible method."

Visible pollination of Vanilla fragrans was more effective than blind pollination.

During the year, a test was made to determine the number of successful pollinations resulting from the use of the blind method as compared with that of the visible method. Table 6 shows the number of successful pollinations resulting from 100 flowers each of two species pollinated by each method.

TABLE 6.—*Beans resulting from pollination of Vanilla fragrans* [1] *and V. pompona flowers by the blind method, as compared with beans produced by the visible method* [2]

Species and method	Vines	Clusters	Pollinations attempted	Beans formed
V. fragrans:	*Number*	*Number*	*Number*	*Number*
Blind	13	30	100	68
Visible	14	35	100	92
V. pompona:				
Blind	7	19	100	93
Visible	7	19	100	88

[1] Pollinations made Mar. 7; beans counted Apr. 9, 1936. [2] Experiment by Pennington.

A comparison of the percentage of successful pollinations of *V. fragrans* by the blind method with that by the visible method shows a significant superiority of the latter.

Although visible pollination was more effective than blind pollination of *V. fragrans*, it is recommended that both methods be used interchangeably; the position of flowers in some instances may cause the blind method to have a certain advantage over the visible method.

Visible pollination of Vanilla pompona showed no significant superiority over blind pollination.

A study of the respective percentages of successful pollinations of *V. pompona* presented in table 6 shows a slight advantage for the blind method, which, however, was not statistically significant. The blind method can be executed more quickly than the visible method and is therefore more economical for semiskilled laborers to use. Because the larger size and sticky nature of the pollen of *V. pompona* seems to make pollination by the blind method successful in a large percentage of cases, the economy of the method should probably give it preference for this species of vanilla.

Progress was made in processing vanilla beans.

The practices used in processing or curing vanilla beans vary widely in different countries where commercial vanilla is produced. To compare some of these practices, experiments were undertaken in which green beans were submitted to different curing methods.

The sun treatment followed in Mexico was used as a basis of comparison. In this process the beans were placed on woolen blankets and exposed to the direct rays of the sun for several successive days, the beans being moved indoors and wrapped in the blankets to conserve the heat when it rained or the sun was not shining.

A second method tested consisted in immersing the beans in water at a temperature of 80° C. for successive periods of 30 seconds each at 10-second intervals. This process was more economical of labor, more rapid, and also capable of a greater degree of accurate control than exposure to the sun.

Other lots of beans were immersed in solutions of manganese sulphate on the theory that vanillin, the essential constituent of cured vanilla beans, is an oxidation product and that certain manganese salts are expected to act as catalytic agents to hasten or facilitate this oxidation. Separate lots of beans were also exposed to ultraviolet rays, to low temperatures, to artificially heated air, and to ethylene gas.

Ethylene treatment gave largest yield of vanillin crystals.

At the close of the year quantitative analyses to show the amounts of vanillin resulting from the various treatments had not been completed. However, all who observed the treated beans agreed that the exposure to ethylene gave the greatest yield of visible vanillin crystals on the pericarp walls of the beans. The beans treated in this way were also of uniform color, flexible texture, and had an appreciably better and more highly developed aroma. The ethylene treatment was carried on in an ordinary chamber such as is used for the ethylene treatment of citrus fruits.

All work reported here has been done by Charles Pennington, vanilla specialist, working in close cooperation with the plant physiologists, chemist, and other personnel of the station.

BAMBOO INTRODUCTION, PROPAGATION, AND UTILIZATION

Additional bamboo species were introduced during the year.

There is but one commonly grown species of bamboo in Puerto Rico, *Bambusa vulgaris*, which although not indigenous, has apparently been existing in the island for many years. During past years the station introduced and established nine other species: *Bambusa tulda*, *B. arundinacea*, *B. balcooa*, *B. tuldoides*, *Bambusa* sp. (Buddha's Belly), *Dendrocalamus strictus*, *D. giganteus*, *Phyllostachys* sp. 55713, and *Cephalostachyum pergracile*.

From January 1, 1934, to June 30, 1935, the station introduced the following 14 additional species and botanical varieties: *Bambusa pallescens*, *B. longispiculata*, *B. multiplex argentea striata*, *B. multiplex* Alphonse Karri, *B. multiplex disticha* (plain), *B. multiplex disticha* (striped), *Bambusa* sp. 77013 Fat T'o Chuk, *Bambusa* sp. 80873 Fan Taan Chuk, *Dendrocalamus membranaceus*, *D. latiflorus*, *Gigantochloa verticillata*, *Guadua angustifolia*, *Oxytenanthera abyssinica*, and *Shibataea kumasasa*.

During the year five more species were introduced as follows: *Bambusa vulgaris* variegated, *Gigantochloa aspera*, *Phyllostachys reticulata*, *P. aurea*, and *P. mitis*.

The station now has a collection of 29 species and botanical varieties of bamboo if the common *Bambusa vulgaris* is included. All but three of these were obtained through the cordial cooperation of the Division of Plant Exploration and Introduction of the Bureau of Plant Industry. From the work developing in the bamboo-utilization shop it seems possible that from among these species will develop one of the most extensive and profitable new crops in the island.

Of the bamboos introduced during the last 2 years, *Bambusa longispiculata*, *Dendrocalamus membranaceus*, *D. latiflorus*, *Gigantochloa aspera*, *G. verticillata*, *Phyllostachys reticulata*, and *Guadua angustifolia* are noted in the literature and correspondence as being large and valuable industrial species.

Bamboo plants were distributed during the year.

During the year, 391 plants of bamboo other than the common *Bambusa vulgaris* were distributed to planters throughout the island. The largest number of these plants consisted of *B. arundinacea*, but there was also some distribution of *B. tulda* and *Dendrocalamus strictus*. *B. arundinacea* is the largest species at the station to date, with a thick wall, the inner part of which, however, is somewhat pithy. This species has shown itself valuable for the construction of farm bridges, corrals, and such things, but seems to have little value for furniture. *B. tulda* is a closely grained, very hard species resistant to boring insects, which is of value for furniture manufacture. *D. strictus* is the solid bamboo, also valuable for furniture construction. All these species are in great demand, and there has not been a supply adequate to fill the requests for planting stock.

To provide additional propagating material, there have been planted and are now growing on the station grounds 130 clumps of *Bambusa arundinacea*, 136 *B. tulda*, 200 *Phyllostachys* sp., 15 *Dendrocalamus strictus*, and 3 *D. giganteus*. At the close of the fiscal year there were possibly 550 young bamboo plants approaching the stage at which distribution could be made.

The station wishes to express its appreciation to the Puerto Rico Reconstruction Administration for its help in the form of field labor which was used in the propagation of these bamboo plants, contributed during the year.

Some bamboo species are difficult to propagate.

Probably the most widely known method of propagating bamboo has been to cut the culm a foot or so from the ground and transplant the stump with as many of its roots as possible. This method of propagation in the experience of the past year has been sure but slow, and any considerable extension of a new species would require at least 10 to 15 years if this method alone were followed.

Another method has been to cut the culm into short lengths of two nodes or more each. The hollow parts at the ends of these seed pieces were then filled with moist loam and the seed pieces planted horizontally in furrows, similar to the method used for planting sugarcane cuttings. The percentage of germinations during the past year by this method of culm cuttings was good for *Bambusa arundinacea*, but comparatively poor for *B. tulda* and *Dendrocalamus strictus*.

The third method consisted of marcottage or layering, which was practiced to a slight extent during the year. By this method loamy soil, rich in nutrients, was packed around a joint of a culm of an age selected as of probable optimum for germination. The soil was held around the node to be germinated by jute cloth held in place by twine. In the moist climate of Mayaguez from May to November such soil was kept moist and favorable to the germination of root and stem eyes. This method also seemed slow, somewhat expensive, and resulted in many failures.

A method of rapid propagation of bamboo.

A fourth method that has had the best success during the year consisted in excavating a complete culm of the species to be propagated, including as many as possible of the roots extending from the base. After the culm had been excavated from the parent clump, it was laid to one side and the lateral branches were pruned to within 6 or 8 inches of the main stem. A few of the secondary branches with a few well-matured leaves were allowed to remain. The retention of well-matured leaves is believed preferable because their water requirement is much less than that of newly forming leaves.

The whole culm with the roots attached was then moved to the propagation field where it was laid horizontally, without any cutting or division, in a furrow previously prepared for it. The whole culm was buried, including the butt and all of the joints for the full length of the culm. By this method a new young plant usually developed at each joint of the bamboo. Experience during the year showed that efforts to transplant the new plants were not successful until a good root system had been developed at each joint, inasmuch as for several months the small plants arising at each joint apparently are drawing a considerable portion of their nutrients from the seed-piece culm and main roots of the parent culm. Subdivision of the plants and their removal before a new root system formed resulted in the wilting and killing of the new plant.

In subdividing the plants arising at each node, the soil was excavated at the center of each internode, and with a small saw the parent culm

was cut. The small excavation necessary for the sawing was then refilled and the plant allowed to remain another month so that the plant recovered from the jarring and shaking which had been caused by the sawing. After such an interval to reestablish the roots, the plants were transplanted to the permanent position where they were to be grown.

This method of propagation has been successful with *Bambusa tulda* and *Dendrocalamus strictus*, both of which were found difficult to propagate by other methods. The principles of this method were outlined for this project by R. A. Young, of the Division of Plant Exploration and Introduction. Armando Arroyo, junior scientific aide, has been in charge of bamboo introduction and propagation and the botany of these species during the year.

FIGURE 10.—Articles constructed from bamboo suitable for furnishing an office or living room. Advances have been made during the year in lessening the attacks of boring insects in the bamboo used for furniture construction.

New method of propagation will accelerate farm plantings.

The station has had only 5 clumps of *Bambusa tulda*, 26 clumps of *Dendrocalamus strictus*, and 1 clump of *B. arundinacea* with which to begin propagation. It was obvious that with such small sources of material, propagation by means of rooted stumps would require years before any considerable areas of these valuable bamboos would be available for industrial or farm use. With the method just described some of the recently germinated plants are being grown as sources for further propagating material, and in the next few years it should be possible to pyramid the numbers of plants available for distribution.

New furniture designs and construction methods.

Simplified designs of several articles have been developed, lessening the costs of fabrication and difficulties for mass production. Figures

10 and 11 show some of the new types of articles designed and constructed during the year. Such articles include simplified and perhaps more pleasing forms of ashtrays, tobacco pipes, a lounge chair, office desk, desk lamp, a bed lamp, beds with take-down joints, a day bed, porch swing, and children's furniture.

A method of weaving royal palm leaves has made possible new furniture designs.

A method of weaving the dried leaves of the royal palms, *Roystonea* (*Oreodoxa*) *regia* and *R. borinquena*, that had been in use in years past was adapted to the use of the manufacture of seats and backs of bamboo chairs and benches and the footboards and headboards of beds.

FIGURE 11.—Some of the articles of furniture constructed from bamboo suitable for a bedroom. It has been found that the woods of certain species of bamboo are better adapted for specific types of construction than others.

Powder-post beetle important factor in new bamboo industry.

During the year it was found that damage to bamboo wood by the powder-post beetle *Dinoderus minutus* Fabricius was even more widespread than was noted in 1935. This beetle is a cosmopolitan species, well distributed throughout the Tropics but is particularly common in Puerto Rico where it feeds in flour, sweet corn, and the wood of several plants. The common bamboo, *Bambusa vulgaris*, is highly susceptible to attacks by this beetle. It became apparent during the year that furniture constructed from bamboo would require some form of preventive treatment if culms of *B. vulgaris* were used. A technique for testing such treatments was developed and the following paragraphs present some of the results of the experiments completed during the year.

For these series of tests standardized metal cages were employed which measured approximately 2 feet long, 18 inches high, and 18 inches wide. The ends and tops of the cages were screened with 30-mesh copper-wire cloth to permit the passage of air. One end of each cage was detachable in order to permit the placing of test pieces and insects in the cages and their removal after the test.

Into such a cage on wire supports 10 replicated strips of bamboo of a given treatment were placed in a randomized arrangement, with 10 replicated standardized strips of identical bamboo for each of several other chemical or preventive treatments. The standardized bamboo test pieces were arranged at random in such a way that heavy infestation of any series of test strips could not be attributed to their position in the cage. The standardized bamboo strips for exposures to the beetle attack in these experiments were taken from culms of *Bambusa vulgaris* because of its great susceptibility.

When the treated standardized bamboo strips were in the cage in final arrangement, 500 to 600 individuals of the powder-post beetle, *Dinoderus minutus*, were blown into the cage, the screened end was fastened into place enclosing the beetles, and the test strips were left exposed to the powder-post beetles for a definite period, usually approximating 30 days.

At the expiration of this period the detachable end was removed, and the numbers of borer channels were counted in each test strip. This type of exposure test apparently resulted in some definite indications as to the value, or lack of value, of the different preventive treatments employed.

Dilution of creosote with kerosene or alcohol lessened effectiveness of beetle control.

On December 18, 1935, eight pieces of split bamboo, each 18 inches long and one-half inch wide, were taken from the butt, and eight pieces of equal size from the top, of each of five whole culms of *Bambusa vulgaris*. Each culm was cut from a separate bamboo clump December 17, 1935. One piece from the top and one piece from the butt of each culm were treated with different concentrations of creosote in kerosene and in alcohol. Each treatment was carefully and thoroughly applied with a paint brush to all surfaces of the bamboo pieces to be tested.

The treated pieces were placed in a screened cage as previously described. On December 23, 1935, after the treated pieces were well dried, 325 powder-post beetles were blown into the cage in equal numbers on each shelf of bamboo sticks, and the cage sealed. There appeared to be no fatalities of the beetles from contact with the treated pieces.

On January 7, 1936, 300 additional beetles were added in the same manner as was employed previously and the cage again sealed. On January 21, 1936, the cage was opened and a count of separate borings made.

The same experiment was repeated with strips of bamboo from culms cut on December 26, 1935, treated January 3, 1936, infested January 8, reinfested January 23, and results tabulated February 6. Results of the two experiments are shown in table 7.

TABLE 7.—*Results of 2 experiments to determine the effect of creosote solutions as treatments for bamboo against attack by the powder-post beetle* [1]

Treatment	Separate beetle attacks					
	Experiment no. 1			Experiment no. 2		
	Tops	Butts	Total	Tops	Butts	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Pure creosote	0	0	0	2	6	8
Creosote 1 part, kerosene 1 part	1	9	10	1	9	10
Creosote 1 part, kerosene 2 parts	2	12	14	7	20	27
Creosote 1 part, kerosene 3 parts	1	41	42	13	39	52
Creosote 1 part, alcohol 1 part	0	22	22	3	14	17
Creosote 1 part, alcohol 2 parts	1	13	14	8	19	27
Creosote 1 part, alcohol 3 parts	0	9	9	6	30	36
Check, no treatment	11	41	52	34	117	151
Total	16	147	163	74	254	328

[1] Experiment by Lee, Watson, and Gibbons.

While creosote gave some measure of control in these experiments, it was thought that better repellents could be evolved. Apparently dilution of the creosote with kerosene or alcohol lessened its effectiveness for insect control. Other than the application pure creosote, none of the treatments could be considered successful.

It seemed evident that the resistance of the tops of whole bamboo culms was much greater than that of the butts.

Tops of normal bamboo culms were less subject to beetle attack than butts.

The foregoing results attracted attention to the different degrees of susceptibility of different parts of the culm, and experiments with preventive treatments were therefore temporarily discontinued until position-susceptibility tests could be made.

TIER NO.	0	1	2	3	4	5	6	7	8	9
9	G	I	F	D	A	C	H	E	J	B
8	H	J	G	E	B	D	I	F	A	C
7	B	D	A	I	F	H	C	J	E	G
6	F	H	E	C	J	B	G	D	I	A
5	E	G	D	B	I	A	F	C	H	J
4	D	F	C	A	H	J	E	B	G	I
3	J	B	I	G	D	F	A	H	C	E
2	A	C	J	H	E	G	B	I	D	F
1	I	A	H	F	C	E	J	G	B	D
0	C	E	B	J	G	I	D	A	F	H

POSITION OF SAMPLE BAMBOO TEST PIECES IN TIER

FIGURE 12.—Arrangement of standardized bamboo test pieces in insect cage in experiment to determine susceptibility of various parts of the bamboo culm to attack of the powder-post beetle.

On January 23, 1936, two normal culms of *Bambusa vulgaris* were cut from two different clumps and divided into 18-inch lengths. Ten split sticks, each about one-half inch wide, were cut from each of 10 selected 18-inch lengths, and in this way 10 samples of bamboo were secured from specified heights in the culms. The sticks were placed in one of the test cages, and on January 24 the cage was infested with 500 powder-post beetles by blowing 50 beetles onto each shelf of bamboo sticks after which the cage was sealed. The cage was opened and the numbers of beetle attacks tabulated February 27.

Figure 12 shows the doubly restricted 10 by 10 randomized latin-square arrangement of sticks in the cage; the shelves were numbered 0 to 9 from bottom to top. This arrangement is shown in detail here

in order to give an understanding of the methods followed in conducting all subsequent bamboo-resistance experiments.

Table 8 shows the relationship of the symbol letters in the foregoing chart to the height from the ground from which the test sticks were taken, as well as the results of exposure to the beetles as indicated by total number of beetle attacks per each set of 10 samples.

TABLE 8.—*Number of attacks by the powder-post beetle according to the position of the bamboo in the culm* [1]

Symbol	Position in culm (height from ground)	Separate beetle attacks per 10 bamboo sticks		Symbol	Position in culm (height from ground)	Separate beetle attacks per 10 bamboo sticks	
		Experiment no. 1	Experiment no. 2			Experiment no. 1	Experiment no. 2
	Feet				*Feet*		
A	0–1½	209	85	F	21–22½	84	65
B	3–4½	183	95	G	27–28½	78	99
C	6–7½	155	124	H	30–31½	101	85
D	9–10½	211	84	I	33–34½	70	73
E	15–16½	123	108	J	39–40½	27	71

[1] Experiment by Lee, Watson, and Gibbons.

In spite of the fact that there was a considerable variation within a given series of test strips from any one position in the culm, nevertheless it was quite evident in this experiment that a gradient of decreasing susceptibility existed from the bottom to the top of normal culms.

Second experiment showed tops of normal bamboo culms less susceptible than butts.

On March 2, 1936, two normal culms of *Bambusa vulgaris* were cut and each divided into 18-inch lengths, as in the case of the experiment just recorded. Five split pieces about one-half inch wide were cut from each of 10 selected 18-inch lengths from each culm, thus securing 10 samples of bamboo from various known heights. The test sticks were placed in one of the insect cages in the doubly restricted 10 by 10 randomized latin-square arrangement recorded above. On March 7, the cage was infested with 500 powder-post beetles by blowing 50 beetles onto each shelf of bamboo sticks, and the cage was then sealed. The cage was opened and the results tabulated 1 month later, on April 7. Table 8 shows the height from the ground from which the sticks were taken and the total number of beetle attacks per each set of 10 samples.

Although the gradient of susceptibility appearing in this experiment from the bottom to the top of these culms was not so marked or so uniform in progression as that recorded in the previous experiment, the results here tabulated corroborated the finding that a gradient of susceptibility did exist.

Topping of bamboo culms tended to remove the gradient of susceptibility.

On January 23, 1936, one topped and one untopped culm of *Bambusa vulgaris*, of identical age and selected from the same clump, were cut and divided into 18-inch lengths. Ten split pieces about one-half inch wide were cut from each of five 18-inch lengths selected at different heights in the untopped culm and from five coinciding lengths

selected from identical heights in the topped culm. The sticks were placed in one of the test cages and on January 27 were infested with 500 powder-post beetles by blowing 50 beetles onto each shelf of bamboo sticks. The cage was opened 1 month later and the results tabulated. The arrangement of sticks in the cage was a doubly restricted 10 by 10 randomized latin square similar to that used in the experiment presented in detail.

The experiment was repeated with culms cut March 2, infested March 7, and results tabulated on April 8. Results of the two experiments are shown in table 9.

TABLE 9.—*Results of 2 experiments to determine the susceptibility to beetle attack of bamboo from various heights in both topped and untopped culms* [1]

Position in culm, height from ground (feet)	Separate beetle attacks per 10 bamboo sticks			
	Experiment no. 1		Experiment no. 2	
	Topped	Untopped	Topped	Untopped
	Number	*Number*	*Number*	*Number*
1½- 3	208	269	89	146
8½- 9	270	263	139	153
13½–15	195	78	131	124
16½–18	336	97	88	118
19½–21	308	96	125	105

[1] Experiment by Lee, Watson, and Gibbons.

The results corroborated those obtained in previous experiments which showed that untopped culms exhibited a definite susceptibility gradient decreasing from bottom to top of culm. However, it is apparent from the data that the definite susceptibility gradient found in untopped culms is not present when the culm is topped.

Soaking in fresh water lessened beetle attack on bamboo.

On January 8, 1936, an untopped culm was cut from a clump of *Bambusa vulgaris* and 60 test strips 18 inches long by one-half inch wide were cut from about midway in the height of the culm. Ten of the strips were soaked in a 5-gallon tin of fresh water; the rest of the strips were placed in an insect-proof cage and later placed in the water with the first 10 strips at such times that by 12 noon of January 22, 10 of the strips had soaked 2 weeks, 10 for 1 week, 10 for 96 hours, 10 for 48 hours, 10 for 24 hours, and 10 had not been soaked. The strips were taken from the water at this time and dried in the noon sun for 1 hour on each side. They were then placed in one of the test cages, at randomized positions with one example of each treatment on each one of the 10 shelves. Three hundred powder-post beetles were then blown into the cage with an equal number on each shelf of bamboo strips, and the cage then sealed. On February 1, 200 additional beetles were placed in the cage in the same manner and the cage was again sealed. On March 1 the cage was opened and a count of separate borings made. The results, although irregular in gradient, indicated that soaking in fresh water for a period of 2 weeks definitely lessened the attractiveness of the bamboo to the powder-post beetle. For economy of space the tabulated results are not presented here since the results of more complete experiments are presented in table 10.

Six weeks' soaking in water minimized borer attack.

In this experiment a slight change was made in the technique of these tests. Rings cut from the bamboo were used as the standardized test pieces, instead of the flat pieces of split bamboo used in the previous experiments. This change was made in order to obtain more representative susceptible surfaces to present to the borers in the test cages than was often possible with the flat strips of split bamboo.

On March 7, 1936, 81 rings three-fourths of an inch thick were taken from an untopped culm of *Bambusa vulgaris* that had been cut on March 6. Nine rings were used in each treatment, there being 81 rings in all including 9 replicated rings of each of the 9 treatments. The rings for any given treatment were taken at various heights in the culm to avoid the known susceptibility gradient which exists in untopped culms. Nine of the rings were placed to soak in a 5-gallon tin of fresh water on March 12 at 1 p. m. The rest of the rings were placed in an insect-proof cage and later placed in the water with the first nine rings in such a manner that by 1 p. m. on April 23 nine of the rings had soaked 6 weeks, nine 4 weeks, nine 2 weeks, nine 1 week, nine 96 hours, nine 48 hours, nine 24 hours, nine 12 hours, and nine had not been soaked. The water was changed each time that new rings were added. The rings were taken from the water at this time and dried in the sun for 1 hour on each side. They were placed in one of the test cages in nine stacks, each stack containing one each of the nine treatments, with a given treatment in a different position in each of the nine stacks. Fifty powder-post beetles were then placed in each of the stacks on April 24 and the cage sealed. The cage was opened and the insect damage tabulated 36 days later.

The experiment was repeated with rings cut on April 28, 1936, from a similar culm cut on April 27, soaking started April 29 at 8 a. m., the rings taken from the water on June 10 at 8 a. m., infested on June 13, and results tabulated 35 days later. In this experiment instead of placing the rings to soak at various times they were all placed in the water at the same time and removed as their soaking periods ended, after which they were placed in an insect-proof cage until the time when they were all exposed to infestation. The water was not changed at any time in this experiment, but in all other respects the procedure of both experiments was identical. Results of the two experiments are shown in table 10.

TABLE 10.—*Results of 2 experiments to determine the effect of soaking in fresh water on resistance of bamboo to attack by the powder-post beetle* [1]

Period of soaking in water	Beetle attacks per 9 bamboo rings		Total	Period of soaking in water	Beetle attacks per 9 bamboo rings		Total
	Experiment no. 1	Experiment no. 2			Experiment no. 1	Experiment no. 2	
	Number	*Number*	*Number*		*Number*	*Number*	*Number*
Check, no soaking	178	37	215	1 week	56	21	77
12 hours	102	48	150	2 weeks	54	21	75
24 hours	142	44	186	4 weeks	45	19	64
48 hours	115	42	157	6 weeks	31	16	47
96 hours	67	20	87				

[1] Experiment by Gibbons and Watson.

These results show that soaking in fresh water for a period of from 96 hours to 6 weeks appreciably lessened the attractiveness of the bamboo to the powder-post beetle, with the 6-week soaking period much the most effective of those tested. By averaging the results of the two experiments, which would smooth out the gradient of susceptibility to the borer, it was seen that soaking the bamboo for 6 weeks reduced its susceptibility to infestation to less than 22 percent of that of the unsoaked bamboo; an end well worth while in bamboo to be used for furniture manufacture.

Salt water lessened bamboo susceptibility more than soaking in fresh water.

The same procedure followed in the two fresh-water soaking experiments was applied in two experiments utilizing salt water. A 4-percent solution of sea salt was utilized in this work, in an effort to approximate sea water. The only difference between these two experiments and the two fresh-water experiments, other than the nature of the water used, was the dates on which the cages were infested and tabulated; all other details were identical. Salt-water experiment no. 1 was infested on April 25 and results tabulated 36 days later, and salt-water experiment no. 2 was infested on June 15 and results tabulated 35 days later. The results of the two experiments are shown in table 11.

TABLE 11.—*Results of 2 experiments to determine the effect of soaking in salt water on resistance of bamboo to attack by the powder-post beetle* [1]

Period of soaking in salt water	Beetle attacks per 9 bamboo rings		Total	Period of soaking in salt water	Beetle attacks per 9 bamboo rings		Total
	Experiment no. 1	Experiment no. 2			Experiment no. 1	Experiment no. 2	
	Number	*Number*	*Number*		*Number*	*Number*	*Number*
Check, no soaking	254	49	303	1 week	44	29	73
12 hours	146	30	176	2 weeks	28	73	101
24 hours	145	17	162	4 weeks	31	6	37
48 hours	180	18	198	6 weeks	27	4	31
96 hours	93	24	117				

[1] Experiment by Gibbons and Watson.

These results show that soaking in salt water for a period of from 96 hours to 6 weeks appreciably lessened the attractiveness of the bamboo to the powder-post beetle, with the 6-week soaking period the most effective of those tested. The averaged results of the two experiments show a reduction in susceptibility to infestation in the bamboo treated for 6 weeks to about 10 percent of the degree of infestation in the untreated bamboo.

It would appear from a comparison of the fresh-water soaking experiments with the salt-water soaking experiments that salt water was more effective in controlling powder-post beetle attack in bamboo.

The susceptibility of the culm butts in untopped bamboo, together with the lessened susceptibility of bamboo after soaking in water, led to the inference that the presence or absence of nutrients in the bamboo may be one factor contributing to susceptibility or resistance to the powder-post beetle.

Paris green spray was effective control against beetle attack on bamboo.

On March 6, 1936, 81 rings three-fourths of an inch thick were cut from an untopped culm that had been taken on March 2 from a clump of *Bambusa vulgaris*. Nine rings, each from a different height in the culm were used in each treatment, and each ring was sprayed separately. In all 81 rings were used, there being 9 treatments and 9 replicated rings of the standardized bamboo test pieces for each treatment. The test pieces for any given treatment were taken at various heights in the culm to avoid the known susceptibility gradient which exists in untopped culms. The solutions or suspensions of preventives were applied by spraying on March 9.

The rings were allowed to dry for 3 days after spraying and on March 12 were placed in a standardized test cage. The test pieces were placed in nine stacks, each stack containing one each of the nine treatments, with a given treatment in a different position in each of the nine stacks. The stacks were then strung horizontally on wires within the cage and each stack was infested with 50 powder-post beetles and the cage sealed. The cage was opened and results tabulated 30 days later.

The experiment was repeated with rings cut on April 23, from an untopped culm cut on the same date, treated April 24, infested April 27, and results tabulated 35 days later. In this experiment the stacks were not strung horizontally on wires but were placed vertically on the bottom of the cage. In all other respects the procedure of both experiments was identical. Results of the two experiments are shown in table 12.

TABLE 12.—*Results of 2 experiments to determine the effect of spray treatments on susceptibility of bamboo to attack by the powder-post beetle* [1]

Treatment	Proportions used	Separate beetle attacks per 9 bamboo rings		Total
		Experiment no. 1	Experiment no. 2	
		Number	*Number*	*Number*
1. Sodium arsenate	1 pound to 5 gallons of water	4	8	12
2. Calcium arsenate	do	8	12	20
3. White arsenic	do	9	6	15
4. Lead arsenate	do	15	20	35
5. Paris green	do	0	1	1
6. Lime-sulphur, ammonium sulphate	16 pounds, 16 pounds, 2½ pounds to 50 gallons of water.	3	36	39
7. Sodium fluoride	1 pound to 5 gallons of water	7	27	34
8. Paradichlorobenzene and kerosene	1 pound to 5 gallons of kerosene	11	26	37
9. Check, no treatment		12	37	49

[1] Experiment by Gibbons.

The conclusion would seem evident that a suspension of paris green, 1 pound in 5 gallons of water, was a considerable deterent to attacks of the powder-post beetle in bamboo.

The rings used in the first experiment were stacked outside the test cage after tabulation, with each treatment in a separate stack, and were left exposed to shop-room conditions for 51 days from April 11 to June 1, when they were again examined. At that time rings sub-

jected to treatment nos. 2, 3, 4, 6, and 8 were found to be very heavily infested, treatment no. 1 to have 7, or only 3 additional attacks; treatment no. 5, paris green, to have no additional attacks, and treatment no. 7 to have a total of 11, or 4 additional attacks.

These data suggest a use for paris green as a preventive of beetle attack in the curing shed and on construction members where its color would not be objectionable, where it would not be exposed to heavy rainfall, or where it would not constitute a hazard to the health of humans or domestic animals.

Creosote solution, dipped hot, effective in control of beetle.

On March 7, 1936, 81 rings three-fourths of an inch thick were taken from an untopped culm of *Bambusa vulgaris* that had been cut down on March 6. The rings were dipped on March 10 by immersing them in one-half inch of the liquid under test, for 30 seconds on each side. The liquid penetrated to some extent in each case; when hot solutions were used, they were kept at the boiling point.

Nine rings were used in each treatment, and each ring was dipped separately. In all, 81 rings were used, there being 9 treatments of 9 replicated rings each. The rings for any given treatment were taken at various heights in the culm to avoid the known susceptibility gradient which exists in untopped culms.

The rings were allowed to dry 3 days, and on March 13 were placed and infested as described in experiment no. 1 on spray treatments just recorded. The cage was opened and results tabulated 29 days later.

The experiment was repeated with rings cut on April 23, from an untopped culm cut on the same date, treated April 25, infested April 28, and results tabulated 34 days later. In this experiment the rings were placed and infested as described in experiment no. 2 on spray treatments. The results of the two experiments are shown in table 13.

TABLE 13.—*Results of 2 experiments to determine the effect of preservative treatments on susceptibility of bamboo to attack by the powder-post beetle* [1]

Treatment	Proportions used	Separate beetle attacks per 9 bamboo rings		Total
		Experiment no. 1	Experiment no. 2	
		Number	*Number*	*Number*
1. Creosote no. 1	Undiluted, hot	1	2	3
2. Creosote no. 2	do	13	0	13
3. Solution no. 3	do	0	1	1
4. Paraffin	do	16	15	31
5. Boiled linseed oil and kerosene	1 to 1, hot	12	35	47
6. Sodium silicate and water	1 to 4, cold	28	91	119
7. Sodium arsenate and water	1 pound to 5 gallons, cold	15	28	43
8. Sodium fluoride and water	do	27	43	70
9. Check, no treatment		65	120	185

[1] Experiment by Gibbons.

The rings used in experiment no. 1 were stacked outside the test cage after tabulation, with each treatment in a separate stack, and were left exposed to shop-room conditions for 51 days from April 11 to June 1, when they were again examined. At that time rings subjected to treatments nos. 4, 5, and 6 were found to be very heavily

infested, treatment no. 1, creosote no. 1, to have no additional attacks, treatment no. 2 to have 23, or 10 additional attacks, and treatment no. 8 to have 29, or 2 additional attacks.

It is evident from table 13 that creosote no. 1 and solution no. 3, both proprietary compounds, used hot, were the most effective of the solutions tested, and that they did provide effective control. However, creosote no. 1 was not further attacked by the beetle in the additional 51 days of exposure under shop-room conditions, while solution no. 3 did show seven additional attacks during this time and also remained sticky and retained a disagreeable odor. For use on construction members where its deep-brown color is not objectionable creosote no. 1 provided the best control. Other desirable qualities are that it dried quickly and did not retain a disagreeable odor.

Bamboo exhibits were awarded gold medal and silver cup.

An exhibit was prepared and displayed during December at the agricultural fair held by the Federal Emergency Relief Administration on the grounds of the College of Agriculture and Mechanic Arts of the University of Puerto Rico in Mayaguez. This exhibit showed not only the products prepared from bamboo, but also specimens of the different species of bamboo which could be utilized in bamboo manufactures.

A handsome 24-inch silver cup was awarded to the station by the committee on awards "in recognition of the merit of its bamboo propagation and utilization project and its potential value for the rehabilitation of Puerto Rico."

During February the regional exposition at the Municipal Building in Mayaguez was completed, and a gold medal was awarded to the exhibit of the experiment station consisting of articles manufactured from bamboo.

A similar exhibit of bamboo furniture and novelties was displayed at the F. E. R. A. exhibition at Isabela in April and elicited favorable comments and interest.

An exhibit of bamboo furniture and novelties of the same nature was sent to New York to be displayed as part of the commercial exhibit of the Insular Department of Agriculture and Commerce.

The shop for experimentation with bamboo construction and the use of preventives against the powder-post beetle infestation has been in charge of Donald F. Gibbons, who was loaned to the station by the F. E. R. A. and later employed by the station in charge of the bamboo-utilization shop; the details of new designs, new methods of construction, and experimentation in insect control have been developed by him in cooperation or conference with other members of the station staff. It is a pleasure to acknowledge at the same time many helpful suggestions concerning the biology and handling of the powder-post beetles from Harold K. Plank, associate entomologist of the Bureau of Entomology and Plant Quarantine.

VEGETABLE CROP INVESTIGATIONS

Types of calabazas have been collected for genetic and plant-breeding studies.

Calabazas are one of the most popular vegetables in Puerto Rico, not only with Puerto Rican Americans, but also with continental Americans living and visiting in the island. Most continental

Americans who have eaten Puerto Rican calabazas profess to like them better than the pumpkins of the continent.

The calabaza, *Cucurbita* sp., is spontaneous after cultivation in Puerto Rico, and there are many forms which can be readily substituted for the North American grown pumpkin and squash. There are no named varieties of calabazas, and the different types of fruits found at the municipal markets are innumerable. Fruits representing 92 different types were collected in approximately 3 hours' time on two visits to the Rio Piedras market. The fruits were weighed, measured, described, and photographed both entire and cut axially; and the maximum and minimum flesh thickness and accurate color descrip-

FIGURE 13.—Group of calabaza fruits, *Cucurbita* spp., representing 28 of 92 different types collected at the Rio Piedras market in April and May 1936, the seed of which are being used in genetic and plant-breeding studies.

tions of the flesh were recorded for each fruit. The seed from these fruits are being used for plant-breeding and genetic studies.

Fruits representing 28 of the 92 different types of calabazas which were collected are shown in figure 13. This picture gives an idea of the variability of these types as well as of the possibilities they afford for breeding studies, not only for Puerto Rican culture, but possibly for continental American production also.

The true yam, Dioscorea spp., is well adapted to the heavy clay soils of western Puerto Rico.

The true yam, *Dioscorea* spp., or "ñame", as it is known in Puerto Rico, is an important food crop of the island, ranking in importance among the root and tuber crops next to the sweetpotato, *Ipomoea batatas*, and the yautia, *Xanthosoma* spp. Contrary to the general opinion regarding the adaptability of tuber and root crops to different soil types, ñames have given good results on the heavier types of

soils, and for this reason they seem adapted to western Puerto Rico. On a small-plat basis a maximum yield of yams of more than 21 tons per acre has been produced on the heavy clay soils of the station.

Extent of harvest injury with Potato yam tubers positively correlated with tuber size.

With more than 9,500 Potato yam tubers an analysis was made of the relationship existing between size of tuber and extent of injury sustained during harvest and handling incidental to storage. The tubers were classified into four different size groups, and the tubers within each size group were further classified into three different

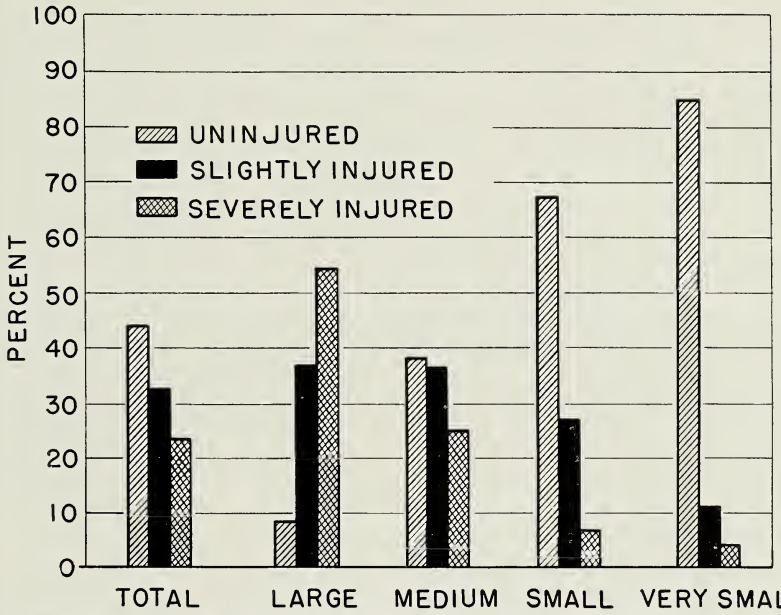

FIGURE 14.—Extent of harvest injury of Potato yam tubers as related to their size, results being expressed as percentage of the weight of the particular size group involved.

injury groups. The results of this analysis emphasized the importance of careful handling of yam tubers during harvesting and storage operations. Extent of harvest injury was found to be very definitely correlated with tuber size; the larger the tubers, the larger was the proportion injured and the larger was the proportion severely injured. More than 91 percent of the large tubers showed some injury; more than 50 percent of them were severely injured, and less than 9 percent escaped injury. This harvest injury-tuber size relationship is shown graphically in figure 14.

Coefficient of variability in yams high.

In the yam-increase-planting plat a high degree of variability has been found to exist among the different hills of the same variety in number of tubers, weight of tubers, and average weight per tuber. Something of the extent of this variability is shown in table 14.

TABLE 14.—*Variation as expressed by the coefficient of variability in number of tubers, weight of tubers, and average weight per tuber, among hills of the same variety for 10 varieties of yams grown in a nonreplicated increase planting at the experiment station during 1935* [1]

Strain or variety	Hills examined	Tubers per hill		Weight of tubers per hill		Weight per tuber	
		Mean	Standard deviation of tuber number per hill in terms of mean [2]	Mean	Standard deviation of single hill weight in terms of mean [2]	Mean	Standard deviation of average weight per tuber in terms of mean [2]
	Number	*Number*	*Percent*	*Grams*	*Percent*	*Grams*	*Percent*
Potato 652	204	24.5±0.63	36.3	654.4± 21.2	46.3	26.9±0.72	37.9
Potato 592	143	26.4±1.02	46.2	714.2± 32.2	54.0	27.7±1.35	58.5
Potato 342	196	22.7± .69	42.7	633.7± 21.9	48.3	28.7± .86	42.2
Potato 103	29	15.4±1.41	49.4	487.0± 27.6	30.6	34.7±2.28	35.4
Potato 44	33	17.6±1.24	40.3	450.2± 39.1	49.8	25.9±1.33	29.3
Potato 125	26	29.0±2.08	36.6	642.5± 46.0	36.5	23.2±1.47	32.3
Potato 133	14	13.4±1.20	33.6	646.4±102.8	59.5	47.1±4.41	35.0
Tongo	122	15.9± .69	48.4	889.5± 40.9	50.8	57.7±1.81	34.5
Morado	46			1,221.6±106.2	59.0		
Ceylon	22			728.2± 83.3	53.7		

[1] Experiment by Bailey.
[2] Coefficient of variability of a single observation.

In three of the Potato yam varieties, tubers of certain of the extremely high-yielding and extremely low-yielding hills and tubers of hills with many and with very few tubers have been used as a basis of a selection study to determine whether these extreme variations in yield and in number of tubers per hill are transmitted vegetatively. Striking variations in shape of tubers were found among hills within the same variety. Some of the most striking of the variations in three of the varieties have been made the basis of hill-selection tests for tuber shape.

A leafhopper was a limiting factor in dry-bean production.

Dry beans constitute one of the basic foods of the people of Puerto Rico; between 30 and 40 million pounds of beans are imported annually. In spite of the fact that the island temperature is considered almost ideal for bean production, yields have usually been low. During the past year, 141 lots of dry beans representing some 17 distinct types from all parts of the world were tested at the station. The results of these tests indicated that one of the limiting factors in dry-bean production, at least in western Puerto Rico, was a leafhopper, identified by H. L. Dozier, associate entomologist of the Bureau of Entomology and Plant Quarantine, as *Empoasca fabalis* DeLong. In two variety plantings, one in January and the other in May of the past year, the leafhoppers attacked the young bean plants soon after they germinated and caused the leaves to die and drop from the plants, leaving them completely defoliated fully 2 weeks before they would have matured normally. Some varieties failed to produce any seed at all; others produced a few seed, but many of these seed were not fully developed. While certain of the varieties of dry beans tested appeared to be more resistant to the feeding of this insect than others, none was commercially resistant.

Of a number of control measures tried, a pyrethrum-soap spray was the only one found to be effective. However, pyrethrum has been too expensive to use on a commercial basis on such a low-value-per-acre crop as dry beans.

Bean pod borers were also important in dry-bean production.

Another factor which has contributed to low yields with dry beans has been the bean pod borer. According to L. B. Scott, associate entomologist, Bureau of Entomology and Plant Quarantine, the three bean pod borers, *Maruca testulalis* Geyer, *Fundella cistipennis* Dyar, and *Etiella zinckenella* Treitschke, have been serious limiting factors in dry-bean production in parts of the island during the past year. In places the infestation was so severe that growers plowed up their bean fields before the crops were mature.

Dry beans were severely injured by the lesser cornstalk borer.

In the dry-bean variety planting made in May, on the Las Mesas upland property of the experiment station, the lesser cornstalk borer, *Elasmopalpus lignosellus* Zeller, did considerable damage. The larvae of this insect either bored into the stems of the young plants and destroyed the tissue there, or completely or partially girdled the stems. An examination of the plants of 10 lots selected at random from among the 141 lots planted revealed that from 5.8 to 44.4 percent of the plants were dead from lesser cornstalk borer injury and many more had fallen over. Those both dead and fallen constituted from 8.7 to 77.8 percent of the total number examined. The true extent of the injury could not be ascertained, for many of the plants which were still standing at the time of the examination had been partially girdled.

Cooperation with the Bureau of Plant Industry in sweetpotato breeding.

Sixty to seventy million bushels of sweetpotatoes are produced annually in the United States, and more than 2¼ million bushels are reported to be harvested each year in Puerto Rico. Yet, very little systematic breeding work has been done with this crop, which is indigenous to the Western Hemisphere and long cultivated by the Indians of Central America and South America. In the continental United States the plants of the varieties of sweetpotatoes commonly grown rarely blossom under natural conditions. This failure to blossom makes sweetpotato breeding difficult on the continent. In Puerto Rico sweetpotatoes usually blossom profusely during the winter months.

This station is assisting the Bureau of Plant Industry with its sweetpotato-breeding program by making some 600 controlled crosses with 8 specified varieties and collecting open-pollinated seed of the same varieties.

Variability in flowering and fruiting of sweetpotatoes.

A consideration of the problems of breeding sweetpotatoes reveals a scarcity of published information on the flowering and fruiting of this crop. During the year it was possible somewhat to increase such information from observations made on the flowering response of the plants in two breeding plats at the station. The following are a few

of the more important findings: Plants of different varieties planted at the same time varied widely in their flowering response; even plants within the same variety differed widely in this respect. In no variety did 100 percent of the plants blossom; some plants that formed blossom buds failed to produce any blossoms. Not all blossom buds formed on the same branch developed into blossoms, for many abscised during various stages of development. Every branch of a plant did not give the same flowering response. The blossoming behavior of the plants could not be associated with age of plants nor with size of plants, either among varieties or among plants of the same variety.

Sterility in sweetpotato varieties.

As indicated by the number of seed produced, a high degree of sterility was found to exist in the sweetpotato varieties studied. Hundreds of blossoms opened but less than 50 seed were produced. Very few insects that might have caused cross-pollination were observed working among the flowers. A definite statement cannot be made at this time as to whether this high degree of apparent sterility was due to inherent genetic factors or to a lack of pollination. The seeds produced by these open-pollinated flowers have been sent to the Bureau of Plant Industry for propagation.

During the past year, as a prerequisite to successful breeding work, a detailed study was made of the time and nature of the dehiscing of the anthers and of the structure of the flower buds of the sweetpotato, using two of the most profusely flowering varieties.

Microscopic examination of all the anthers of more than 150 flower buds of the two varieties over a 3-day period revealed that some of the anthers started dehiscing between 9 and 10 a. m. on the day before anthesis, and by 12 noon all anthers had started to dehisce.

The pollen was not forcibly ejected from the anthers at any time; in fact, the pollen had a somewhat sticky, clinging consistency, and it was comparatively difficult to dislodge it from the surface of the dehisced anthers. Tapping the peduncle of a flower on the day of anthesis did not disturb the exposed pollen grains. In view of these facts it seemed advisable that all emasculations for controlled crosses be made no later than noon and preferably before 10 a. m. on the day previous to anthesis.

American varieties of sweetpotatoes originated chiefly in the West Indies.

Most of the varieties of sweetpotatoes commonly grown in the continental United States have originated in the West Indies. Most sweetpotato plantings in Puerto Rico are of mixed varieties. As a result of chance seedlings coming from seed of open-pollinated flowers, many new forms are doubtless appearing each year. In view of the improvement of other crops by breeding, it seems probable that if a comprehensive collection of types were grown and observed under comparable conditions, some superior forms would be discovered which would constitute a material service to both Puerto Rican agriculture and the agriculture of the southern continental United States.

Indian onions are being tested in Puerto Rico.

Between 7 and 8 million pounds of onions are imported into Puerto Rico annually. Bermuda onions have been successfully and profitably grown in Puerto Rico during the fall and winter months. Well-

grown Bermuda onions have brought good prices on the local markets at all times of the year and on the New York market during February and early March, before the Texas Bermuda crop is harvested. Since Bermuda onions have a short storage life, in the regions of Puerto Rico where onions are grown at present, the planting must be so timed that the plants will reach maturity during the dry season; otherwise the bulbs fail to cure properly without special treatment. The onion varieties that are commonly grown on the continent and keep well in storage do not form bulbs under the short day lengths of the Tropics. As a consequence local-grown onions appear on the market during only about 2 months of the year

Seed of six varieties of onions indigenous to those sections of India which have day length and climatic conditions very similar to those of Puerto Rico have been imported for trial here. In addition, seed of six varieties of onions known to form bulbs under short day-length conditions have been obtained from sources in the continental United States.

Onion thrips are a factor in onion production.

At present the most important limiting factor in the production of onions is the onion thrips, *Thrips tabaci* Lindemann. In cooperation with L. B. Scott, associate entomologist of the Bureau of Entomology and Plant Quarantine, a test was made of the relative effectiveness of seven different insecticides in controlling this insect on Bermuda onions grown at this station from November 26, 1935, to March 20, 1936. The seven treatments and the check were replicated seven times in a latin-square arrangement. Six applications of each insecticide were made at weekly intervals, the first on January 25 and the last February 29. At harvest time the bulbs were divided into marketable and nonmarketable classes. The marketable bulbs were further classified according to size as boilers, small, medium, and large, based on the diameter of the bulbs. The nonmarketable bulbs were divided into splits and doubles, splits and doubles forming bulbs, straight splits and doubles, single straights, and well-formed bulbs too small to market. In table 15 are recorded the treatments used, the mean yield of marketable onions per plat classified by treatments, the yield of marketable onions on an acre basis, the percent increase over the check, and the calculated cost of the insecticidal materials per acre for the six applications.

TABLE 15.—*Relative effectiveness in onion thrips control of various insecticides applied 6 times from Jan. 25 to Feb. 29, 1936* [1]

Treatment	Marketable onions			Cost of insecticidal materials per acre
	Mean yield per plat	Calculated yield per acre	Increase over check	
	Ounces	*Pounds*	*Percent*	*Dollars*
Derris powder spray with commercial sticker and spreader	72.36	821	210	115.26
Derris powder spray	63.63	721	172	112.32
Naphthalene dust	59.63	677	156	49.20
Derris powder spray with sulphonated castor oil	56.50	641	145	116.82
Sulphur and manganese dioxide dust	54.00	612	131	60.20
Nicotine sulphate spray with soap	48.36	549	107	15.87
An organic thiocyanate spray with sulphonated castor oil	26.63	302	14	19.87
Check, no insecticidal treatment	23.36	265	----------	----------

[1] Experiment by Bailey and Scott.

The analysis of variance of yield of marketable onions showed treatments gave highly significant results.

The treatments gave increases over the check varying from 14 to 210 percent. The analysis of variance of the data for the plat yields of marketable onions is shown in table 16.

TABLE 16.—*Analysis of variance of data for yield of marketable bulbs shown in table 15*

Source of variance	Degrees of freedom	Mean square	*F* values
Rows	7	2,045.93	
Columns	7	1,468.36	
Treatment	7	2,391.50	9.8
Error	42	243.79	{5-percent point=2.34. 1-percent point=3.29.
Total	63	8,187.26	

The analysis revealed that the variance due to treatment was highly significant, the odds as indicated by the *F* values being much greater than 99 to 1 that the treatment response was not due to chance.

Six insecticides gave significant increases in yields.

In determining the significance of differences between individual treatments, it was found that a difference of 15.6 ounces between the mean yield per plat for any two treatments was necessary to give significant odds, namely, 19 to 1, that the difference was not due to chance alone. A difference of 21.9 ounces was required to give highly significant odds, namely, 99 to 1, that such an observed difference between two treatment means was due to some factor other than chance.

All of the insecticides used, except the organic thiocyanate with sulphonated castor oil spray, gave highly significant increases over the check in yield of marketable onions. All treatments except the check were significantly superior to the organic thiocyanate, and with all of these except the nicotine sulphate spray the superiority was highly significant. In yield of marketable onions there were no significant differences between the derris powder spray, the naphthalene dust, the derris powder spray with sulphonated castor oil, the sulphur and manganese dioxide dust, and the nicotine sulphate spray.

The derris powder spray with commercial sticker and spreader was the most effective but most costly.

The derris powder spray with a commercial spreader and sticker was the most effective, being significantly superior to all other treatments except the naphthalene dust and the derris powder spray and highly significantly superior to the nicotine sulphate and soap spray, as well as to the organic thiocyanate spray and the check. However, derris has been too expensive to use on a commercial basis for the control of onion thrips in the island, to date.

Nicotine sulphate and soap spray was the most economical and effective.

From a grower's standpoint, the cost of the materials for all of the insecticides used, except that for the nicotine spray and possibly the organic thiocyanate, was so excessive as to prohibit their use regard-

less of the control effected. In comparison with the other insecticides used in this test, the nicotine sulphate and soap spray appeared to be the most practicable control for onion thrips.

Analyses of variance and covariance indicate differences in yields.

After determining the significance of differences between yields of marketable onions for the different treatments, further analyses were made to determine how these differences arose. By means of analyses of variance and covariance it was determined that the increased yields of marketable onions resulting from the insecticidal applications made were brought about by (1) a larger proportion of the plants being able to reach maturity, (2) a larger proportion of the matured plants forming bulbs, (3) a larger proportion of the bulbs formed being marketable, and (4) the marketable bulbs having a larger average weight per bulb because of a greater proportion of larger sized bulbs. The extent to which each of these factors was operative varied among the several treatments as is indicated in table 17.

TABLE 17.—*Some of the ways in which the differences in yields arose for the different insecticidal treatments used in the onion thrips control experiments shown in table 15*

Treatment	Yield of marketable onions per acre	Plants reaching maturity	Matured plants forming bulbs	Bulbs formed which were marketable	Average weight per marketable onion
	Pounds	*Percent*	*Percent*	*Percent*	*Ounces*
Derris powder spray with commercial sticker and spreader	610	72.6	80.9	60.1	0.42
Derris powder spray	540	72.2	81.4	55.1	.40
Naphthalene dust	511	73.0	72.5	58.2	.39
Derris powder spray with sulphonated castor oil	492	74.2	76.0	57.5	.35
Sulphur and manganese dioxide dust	464	66.2	67.5	59.6	.41
Nicotine sulphate spray with soap	419	74.1	58.9	50.6	.38
An organic thiocyanate spray with sulphonated castor oil	245	59.7	56.2	52.3	.31
Check, no insecticidal treatment	220	59.3	51.4	48.9	.32

Experiment emphasized the need for a cheap source of rotenone.

The excellent showing of the rotenone-containing derris sprays in this test indicated the need of a cheaper source of rotenone and emphasized the importance of testing large numbers of tropical rotenone-producing plants in an effort to find a better and cheaper source of this valuable insecticide.

Onions apparently not adapted to the heavy clay soils of the experiment station.

The low yields obtained in this test indicated in a very striking manner that the wet heavy clay soils of western Puerto Rico seem unadapted to onion production. While the highest yield obtained did not even closely approach a good commercial yield of onions, and while the results of the statistical analyses indicated only what response might be expected from the use of the several insecticides under the same conditions as those of this experiment, it was felt that the differential response obtained with the insecticides used would indicate the results that might be expected under similar climatic conditions where soil conditions were more favorable for the growth and development of onions.

Indian cucumbers have given promising results.

During the fall of 1935, 11 lots comprising 9 varieties of indigenous Indian cucumber seed were imported from sections of India where the climatic conditions are similar to those of Puerto Rico. This was done for the purpose of making a preliminary test of these varieties for their resistance to downy mildew.

Several of these cucumbers have given promising results. Not only were the small fruits of good quality, but also the thick fleshy pericarp of the older fruits retained its crisp consistency long after the seeds had begun to harden and the placental tissue had become somewhat tough and stringy. Also the astringency, which is associated with the section of white tissue at the bases of the placentae of most American sorts of cucumbers at the slicing stage, was almost entirely lacking in the Indian varieties tested. Several of the Indian varieties, moreover, made a more vigorous vegetative growth than the Black Diamond, the standard variety grown on the island for export, and the vines appeared to be more tolerant of aphis than those of the Black Diamond. Susceptibility to downy mildew has not as yet been determined.

In their present form these Indian cucumbers may not be good market sorts for the continent because the fruits do not have the dark-green color to which the continental markets are accustomed, but have instead a bronze to pale-green color. However, the color of the fruits in no manner detracts from their eating quality and would not prevent their becoming popular in home gardens throughout the island. Many more tests will be necessary before a final report on the adaptability of these indigenous Indian cucumbers to Puerto Rican conditions can be made.

Fifty-five varieties of soybeans were introduced.

During the past year 55 varieties of soybeans were imported for trial through the cordial cooperation of W. J. Morse, senior agronomist of the Bureau of Plant Industry. Some of these varieties have given promising yields under tropical conditions, but it is too early to present conclusions as to the comparative merits of the different varieties, or as to the adaptability of soybeans to island conditions. Under the influence of the comparatively short periods of summer daylight, soybeans were found to blossom and mature in much less time than in the continental United States. The varieties tested blossomed from 18 to 58 days earlier and produced seed from 35 to 90 days earlier than is reported for the same varieties on the continent. Some varieties blossomed in 29 days, and some produced seed 72 days after planting at this station.

There is an absence of oils and fats at low costs for the diet in Puerto Rico, and the extensive use of soybeans in China and Japan to fill these dietary needs has created interest in this crop for Puerto Rico.

These vegetable crop investigations were conducted by Wallace K. Bailey, associate physiologist, who was assisted in the early part of the year by José Beauchamp, under scientific aide.

SWEET CORN BREEDING AND AGRONOMY

Agronomic practices for production of tropical sweet corn have been improved.

In the annual report for 1935 an account was given of the breeding at the station of two varieties of sweet corn adapted to tropical conditions. Mention was also made of shipping studies in which such

sweet corn was placed in New York without deterioration and met with favorable reception by dealers and consumers there in the winter months. During the past year it has been possible to carry on several well replicated field experiments which have increased the understanding of the agronomic practices that produce the best sweet corn and most profitable yields of two varieties.

USDA–34 sweet corn was significantly superior to USDA–32.

In a variety trial of sweet corn on unirrigated yellow clay lowland at the station the varieties USDA–32 and USDA–34 were compared. There were nine replicated plats of each variety, each plat being one-fortieth of an acre in area. There was excessive rainfall immediately after planting and germination was poor; heavy rates of seeding were used, however, and counts made 1 month after planting indicated that there was no significant difference in the stands of the two varieties. The corn was grown on ridges thrown up by a small double moldboard plow in rows spaced 2½ feet apart with one corn plant every 12½ inches in the row.

The experiment was planted October 1, replanted October 10, and harvested 93 days after planting, January 2, 1936. The results are shown in table 18.

TABLE 18.—*Results of a comparative test of 2 new tropical varieties of sweet corn, USDA–32 and USDA–34, with 9 replicated 1/40-acre plats of each variety* [1]

Variety	Percent of perfect stand Oct. 30 [2]	Ears in silk [3]—		Time to picking	Yields of green ears per acre				
		Dec. 5	Dec. 9		Marketable ears		Average weight per ear	Nubbins	Total weight
	Percent	*Percent*	*Percent*	*Days*	*Number*	*Kilograms*	*Grams*	*Percent*	*Kilograms*
USDA–32	94	44.7	88.1	84	5,312	1,214.4	231.5	43.35	1,724.8
USDA–34	94	39.3	80.7	80	6,588	1,584.8	240.8	36.50	2,068.0

[1] Experiment by Davis, Lee, and Watson. Planted Oct. 1, 1935, harvested Jan. 2, 1936.
[2] Based on counts of 200 hills per plat.
[3] Based on observations of 50 plants per plat.

According to data collected on 450 plants of each variety, there was practically no difference in the number of days from planting to silking of the two varieties. The sweet corn was harvested 24 days after the majority of the silks were out. As shown in table 18, USDA–34 produced 6,588 marketable ears per acre as compared to 5,312 ears produced by USDA–32, a difference of 23.9 percent which statistically was highly significant.

The sweet corn variety USDA–34 produced ears much better filled out at the tip ends than USDA–32 and the difference in weight of marketable ears in favor of USDA–34 was highly significant. USDA–34 ears, nubbins as well as marketable, averaged 9.3 grams heavier than those of USDA–32; although this difference fell just below the level of statistical significance, the superiority indicated was in the same direction as for other characteristics.

The number of nubbins produced by USDA–34 was 36.5 percent of the total number of ears produced, whereas USDA–32 produced 43.35 percent nubbins; this difference was statistically significant.

151502—37——4

The results of this experiment indicate the general superiority of USDA–34, and it is concluded that the breeding and agronomic work with sweet corn should be centered on USDA–34 and that it should replace USDA–32 in marketing tests.

Ammonium sulphate at planting time improved stands of sweet corn.

In a time-of-nitrogen-application experiment for sweet corn on unirrigated silt loam in a lowland field at the station, equivalent amounts of nitrogen from ammonium sulphate and nitrate of soda were applied at planting time and 3 weeks after planting. There were 12 replicated plats of each of the 4 treatments, each plat being one-fortieth of an acre in area. The corn was planted July 22, 1935, and harvested 108 days later. Where fertilizers were applied at planting time, the application was made in the furrow at the locations where seed was to be placed and then covered with soil; the planting then followed immediately. Where the fertilizer was applied 3 weeks after planting, the application was placed near the hills and covered with soil with hoes. The data as to fertilizer quantities and harvest results are shown in table 19.

TABLE 19.—*Harvest results of time-of-nitrogen-application experiment for sweet corn, variety USDA–32, at Mayaguez, using sodium nitrate and ammonium sulphate as sources of equivalent amounts of nitrogen per acre* [1]

[The figures show the average yields of 12 replicated 1/40-acre plats per treatment]

Fertilizer and treatment	Applied per acre	Nitrogen content	Nitrogen applied per acre	Percent of perfect stand Sept. 7	Yields of green ears per acre				
					Marketable ears		Average weight per ear	Nubbins	Total weight
	Pounds	*Percent*	*Pounds*		*Number*	*Kilograms*	*Grams*	*Percent*	*Kilograms*
Ammonium sulphate at planting time	299.8	20.84	62.5	75.6	1,352	298.8	193.4	60	503.6
Ammonium sulphate 3 weeks after planting	299.8	20.84	62.5	59.3	972	178.8	182.5	67	342.8
Nitrate of soda at planting time	400.0	15.62	62.5	65.6	1,072	208.8	196.8	66	376.4
Nitrate of soda 3 weeks after planting	400.0	15.62	62.5	53.4	712	149.2	178.7	65	284.4

[1] Experiment by Davis, Lee, Watson. Planted July 22, harvested Nov. 7, 1935.

The relatively poor stands and yields, secured throughout the experiment, were largely due to mole cricket attack.

Ammonium sulphate applied at planting time gave stands significantly superior to those secured from either fertilizer applied 3 weeks after planting. When both nitrate of soda and ammonium sulphate were applied at planting time, the counts were in favor of ammonium sulphate but the difference was not statistically significant.

Ammonium sulphate at planting time was more effective than nitrogen fertilizers applied later.

Ammonium sulphate at planting time significantly increased both the number and weight of marketable ears over the yields secured with either nitrate of soda or ammonium sulphate applied 3 weeks after planting. Ammonium sulphate yielded both more ears and greater total weight of ears than nitrate of soda when both were applied at planting time, but the difference was not statistically

significant. Nitrate of soda at planting time did not produce yields of marketable ears significantly superior to those secured from plats with nitrate of soda applied 3 weeks after planting. When both fertilizers were applied 3 weeks after planting the ammonium sulphate produced a slightly larger number of ears and weight of ears than the nitrate of soda, but the differences were not significant.

Ammonium sulphate applied at planting time resulted in the production of ears with an average weight of 193.4 grams each, which was superior by more than 10 grams to the average weight of ears produced when either ammonium sulphate or nitrate of soda was applied 3 weeks after planting. There was a slight difference in weight per individual ear in favor of the nitrate of soda when the two different fertilizers were applied at planting time but the difference was not statistically significant.

Ammonium sulphate at planting time reduced the proportion of nubbins.

As shown in table 19, the average percentage of nubbins for the plats treated with ammonium sulphate at planting time was 60, whereas that for the plats treated with the same fertilizer applied 3 weeks later was 67. Nitrate of soda applied at planting time resulted in a production of 66 percent of nubbins and when applied 3 weeks later the production of nubbins was 65 percent, a nonsignificant difference. The superiority of ammonium sulphate at planting time over the other three treatments in production of smaller numbers of nubbins approached closely to significance.

Ammonium sulphate applied at planting time gave results superior, but not significantly so, in total weight of both nubbins and marketable ears as compared with that of plats treated with ammonium sulphate 3 weeks after planting. The application of ammonium sulphate at planting time did, however, give results significantly superior in total weight of ears to those secured from nitrate of soda applied 3 weeks after planting. When both fertilizers were applied at the same time, whether at planting time or 3 weeks later, the differences in yield in favor of ammonium sulphate were not significant.

Sweet corn seed of new varieties was distributed to growers.

Of the new sweet corn varieties, USDA–32 and USDA–34, 548 pounds of seed were distributed to growers in small lots for trials in commercial production. Some of the production from this seed distribution is now being marketed regularly in San Juan stores. Twenty-eight pounds of seed of these two new varieties were distributed to experiment stations and private growers in the Southern States on the continent; enthusiastic statements have been received regarding the success of these varieties from Louisiana and Florida.

The sweet corn breeding and field experiments on agronomic practices were conducted by R. L. Davis, agronomist, who also correlated the work of other men of the staff who contributed from time to time to the corn studies.

A quantitative method of showing root distribution of corn.

It seemed of interest and probable value to corn growers to make studies of sweet corn root distribution in the soil similar to the studies made in past years for sugarcane. Since both plants are large grasses, they both can be studied for many objectives by similar methods.

In making this root study 90-day-old USDA–32 sweet corn plants were selected in a clay soil in the south field at the station; 200 pounds of ammonium sulphate per acre had been applied to this cornfield.

In a row of evenly spaced hills, well removed from the edge of the field, five adjacent hills having two stalks each were selected for excavation and determination of the distribution of their roots. The rectangular area to be excavated for the root study was then staked off and outlined with cord around the five hills after they had been cut, two sides of the area passing parallel to the row under study and midway between it and the adjacent rows. The ends of the rectangle passed outside of hills 1 and 5 and halfway between them and the adjacent hills. This enclosed area was found to contain 21.14 square feet. Before the excavation was started the surroundings were cleared of other corn plants to facilitate the work. Figure 15 illustrates diagrammatically the way the excavated area was laid out.

Roots screened from the soil as different levels were excavated.

The corn had been hilled up in earlier field operations, and the first procedure in these studies was to determine the distribution of the roots of the corn plants in such hilled-up soil. This soil was therefore

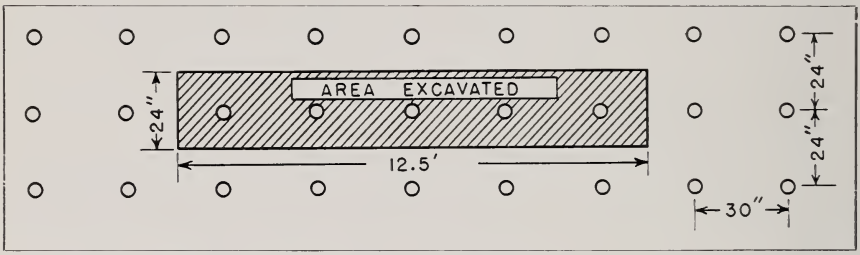

FIGURE 15.—Excavated area for the method used in studying the distribution of corn roots in the soil. Compensation was provided for roots that extended beyond the area of excavation by including roots from adjacent rows that extended into the excavated area; in this the centering of the sides of the excavation exactly midway between the corn rows was important.

lifted in shovels and thrown onto an inclined wire screen of ¼-inch mesh such as is commonly used by building contractors for screening sand. The screen allowed the soil to pass through while the corn roots remained on the upper surface of the screen. All the hilled-up soil in the area under study was thus removed and screened down to the lowest level of the soil between the rows. All roots collected were composited, bagged, labeled, and placed aside for later washing and weighing.

The hilled-up soil and the enclosed roots having been removed, an excavation was made to a depth of 8 inches. The soil and roots thus removed were thrown upon the inclined wire screen; the corn roots thus separated out were composited, bagged, and labeled as before for later washing and weighing.

In a similar way excavations were made of the three subsequent 8-inch layers of soil down to 32 inches in depth. The layer of soil between 24 and 32 inches in depth showed such a small concentration of the roots that further excavation was discontinued.

Corn roots from adjacent rows compensate for roots which extended beyond excavation.

In an isolated planting of a few hills of corn the corn roots which would extend beyond the lateral limits of the excavation would be

lost for any consideration of the comparative weights of roots at different levels of the soil. However, where the study was conducted between regularly spaced rows of corn equidistant from each other, as in this case, the average loss of roots beyond the area excavated was compensated for by the roots that extended into the area excavated from the corn plants in the contiguous rows. The roots separated from the soil layers at different depths were then washed free of all soil, oven-dried, and weighed. The weights and percentages of the roots at the different levels in depth in the soil are shown in table 20.

TABLE 20.—*Weights, percentages, and concentrations of roots of sweet corn plants at different levels in the soil* [1]

Levels of the soil	Weight of roots	Roots per cubic foot of soil	Percentage of roots at different levels	Levels of the soil	Weight of roots	Roots per cubic foot of soil	Percentage of roots at different levels
	Grams	*Grams*	*Percent*		*Grams*	*Grams*	*Percent*
Hilled-up	38.77	5.51	40.4	16 to 24 inches	3.14	0.22	3.3
Surface to 8-inch level	46.22	3.23	48.1	24 to 32 inches	1.22	.08	1.3
8 to 16 inches	6.58	.46	6.9				

[1] Excavations by Gomez; weighings by Carrero.

Eighty-eight percent of roots were found in topmost 8 inches of soil.

It is noteworthy that but 1.3 percent of the roots of the corn plants existed below the 24-inch level. Perhaps even more noteworthy is the fact that but 11.5 percent of the roots existed below the 8-inch level; the balance of the roots existed in the topmost 8-inch layer of soil and in the soil hilled up around the plants.

Similar studies with sugarcane have shown that in looser, more sandy soils the percentage of roots at the lower levels of the soil is frequently slightly greater; the soil in these studies, being a wet clay, possibly had some influence on the small percentage of root distribution in the lower layers. Similarly, in sugarcane root-distribution studies it has been shown that in the early stages of growth the concentrations of roots are much greater in the upper layers of soil than in the lower layers; sweet corn being a quick crop of but 3 or 4 months' growth, the simple factor of short lapse of time should receive consideration as affecting the small concentrations of roots in the lower levels of soil.

It would be unwise to attempt here to draw conclusions for field practices from these determinations, but field men with this background of information concerning the quantitative distribution of the roots of sweet corn in the soil can possibly conduct to better advantage their field practices in tillage, cultivation, drainage, and fertilization.

The studies of the distribution of sweet corn roots in the soil were very largely the work of Luis A. Gomez, scientific aide.

Experiment station lowland soils have high percentage of very fine sand.

It seemed desirable to have physical analyses of the soil from which the foregoing root-distribution studies were made; table 21 gives a tabulation showing such analyses.

TABLE 21.—*Results of physical analyses of soil at different depths in south field of the experiment station in which sweet corn root-distribution studies were made* [1]

Depth from surface (inches)	Proportion of roots by weight	Coarse sand	Medium sand	Fine sand	Very fine sand	Total sand	Silt	Clay
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hilled-up soil	40.42							
0–8	48.18	0.319	2.719	2.777	29.447	35.262	17.848	46.888
8–16	6.86	.354	2.080	2.276	28.698	33.408	19.472	47.118
16–24	3.27	.027	2.912	2.390	26.839	32.168	20.192	47.555
24–32	1.27	.052	1.915	1.575	15.605	19.147	23.571	57.281
Composite sample		.188	2.406	2.225	25.147	29.966	20.271	49.627

[1] Analyses by Rodriguez. U. S. Department of Agriculture standard of classification determined by beaker method.

A casual examination of the soil in which these root-distribution studies were made would lead to the conclusion that it was a heavy, stiff clay. However, it was found that there was a total concentration of 30 percent of sand in this soil, of which 25 percent was very fine sand. It is probably the fineness of the sand that creates the misleading impression concerning this soil; the soil would be classified as a clay.

It should be noted that the percentages of sand separates or particles decreased while the percentages of clay separates increased at the greater depths in the soil.

Greatest concentrations of plant nutrients found in topmost layer of soil.

It was also possible to secure chemical analyses of soil samples taken from the different 8-inch layers of soil excavated in the above sweet corn root-distribution studies. The results of these chemical analyses are shown in table 22.

TABLE 22.—*Results of chemical analyses of soil layers at different depths, from which sweet corn roots were extracted, in the south field at the experiment station* [1]

[All percentages are calculated on dry basis for total content]

Depth from surface (inches)	Acidity	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Silica (SiO_2)	Iron oxide (Fe_2O_3)	Aluminum and titanium oxides (Al_2O_3, TiO_2)	Lime (CaO)	Magnesium oxide (MgO)	Manganese oxide (MnO)
	pH	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hilled-up soil										
0–8	7.80	0.186	0.28	0.392	50.88	12.73	18.70	0.93	3.18	0.113
8–16	7.88	.171	.24	.448	50.92	12.94	19.67	.92	2.37	.117
16–24	8.10	.127	.14	.314	50.10	14.29	19.19	.66	2.54	.128
24–32	7.90	.112	.12	.268	50.10	12.75	21.38	.54	2.07	.090

[1] Analyses by Carrero.

Table 22 shows a slight tendency for the pH value to increase with greater depths in the soil, which possibly would be natural to expect in a soil derived from limestone or sediments from limestone. Even the topsoil was definitely alkaline. As was to be expected, the nitrogen content decreased appreciably at greater depths in the soil, and the phosphoric acid and potash contents showed similar tendencies to decrease.

Correlating with the physical analyses of these soil samples, the silica content decreased at the greater depths, while the aluminum and titanium oxides increased. The lime content was very low and decreased in the lower levels of soil, a somewhat curious phenomenon in a soil of sedimentary origin supposedly initially derived from limestone. The lime-magnesia ratio was very low.

Concentration of roots corresponded in distribution with concentration of nutrients.

Experiments with sugarcane in Hawaii have shown that soil nutrients have little or no chemotropic effect on sugarcane roots, but that when such roots reach a soil area of high nutrient content there is an increased density of roots in such area. In the present studies the greater concentrations of sweet corn roots found in the upper layers of soil are correlated with the higher concentrations of nitrogen, phosphoric acid, potash, lime, and magnesia in these topmost layers of soil.

SHIPPING AND MARKETING INVESTIGATIONS

Winter vegetables have been advantageously grown.

Growers during the last 5 years have found many standard commercial varieties of temperate-zone vegetables well adapted to local conditions. During this same period much knowledge has been obtained about soils, fertilizers, and spraying for the control of insects and diseases. Because of this pioneering, many crops can now be planted with reasonable assurance of a satisfactory yield of good quality.

There are many thousands of acres that are suitable for vegetable growing and upon which many varieties of vegetables both for export to the continental United States and for domestic consumption can be raised in quantities.

Markets for winter-grown vegetables exist in the continental United States.

During certain months of the year production of many varieties of vegetables within the continental United States is of such small quantities that only a small part of the demand is supplied. During these months in many communities these vegetables are not a part of the people's diet. Other cities, mostly on the Atlantic seaboard, obtain limited and irregular supplies from Cuba, Puerto Rico, and other tropical places. During these months of scarcity, December to April, these crops can be produced abundantly and of excellent quality on this island.

Between December 1 and March 30 cucumbers, summer squash, eggplant, Bermuda onions, peppers, tomatoes, corn, okra, string beans, lima beans, and watermelons have been shipped and marketed, usually at a profit to the grower. Local consumption of these products during the last 5 years has also increased.

Agricultural costs per acre are sometimes higher here than in the continental United States, but these costs have generally been offset by higher average prices than those obtained by other producing sections of the United States.

Puerto Rico now has precooling capacity for 22,500 bushel packages weekly, and vessels sailing once each week have refrigeration capacity of approximately 50,000 bushel packages.

In 1932 Puerto Rico growers started to use the grades adopted in the continental United States for fresh vegetables. By 1935 these grades were in general use. The adoption and use of these grades have standardized the pack so that Puerto Rican vegetables have become well and favorably known in the markets where sold.

Factors which limit the marketing of island vegetables.

While Puerto Rico is situated only 4 days from the large cities on the Atlantic seaboard, ocean freight service is such that shipments of any commercial importance can be made only to New York; sailings to other ports are so infrequent that crops cannot be marketed successfully in such markets. Therefore, practically all Puerto Rican vegetables are consumed in New York City or reshipped to other cities, after sale in New York.

New York is the principal port of entry of a large percentage of competing vegetables from other tropical countries. It has, therefore, often happened that during a period of general scarcity of winter vegetables in the continental United States, the city of New York has been oversupplied with such commodities, which were sold at prices ruinous to all growers.

The New York market has always reacted sharply to an oversupply of winter vegetables. During periods of scarcity, there seems no limit to what the market has paid, but the reaction in times of oversupply has been just as great. While Puerto Rican growers have regulated their own shipments, they of course have had no control over shipments from Cuba and other exporting tropical countries. On account of these conditions, market prices have often been below the cost of production and shipment to New York. These conditions could largely be relieved if island shippers had shipping facilities and representatives in other markets such as Baltimore, Philadelphia, and Boston.

There appears to have been no organized attempt by New York receivers to relieve the oversupply that sometimes accumulates in that city, by reshipping to other markets, as is done in the case of pineapples and citrus fruit. Receivers have always sold at New York prices a small percentage of shipments to dealers in other eastern cities, and occasionally have sold carload lots to western dealers. The growers have often forbidden their New York representative to reship for their account, which constitutes one important reason for restriction of sales to the New York market.

Distribution to nearby markets has generally occurred during periods of oversupply. Most of these vegetables have been bought by out-of-town dealers' representatives, or New York jobbers, who buy for speculative purposes, of course at the low prices. These prices have in many cases been below the costs of production. Most reshipments of vegetables from New York have been made by trucks.

Weather conditions in New York are a very important factor in the marketing of winter vegetables. Experience has shown that whenever subfreezing weather occurs, sales of all fresh vegetables and fruits are sharply curtailed, especially tender green vegetables of a highly perishable nature, such as are grown here. Most reshipments from New York have usually been almost completely stopped during periods of subfreezing weather.

As Puerto Rican vegetables, on account of shipping conditions, are only received in New York one day a week, there is often an over-

abundant supply for 1 or 2 days, with a scarcity during the remainder of the week. Many New York retailers have not handled Puerto Rican vegetables on account of not being able to obtain supplies more continuously than once a week.

All of the foregoing unfavorable factors in the marketing of Puerto Rican vegetable products in the continental United States would seem to be subject to control by more extensive cooperation and more detailed distribution arrangements in the northern markets.

Lime shipments have not been selected, graded, or wrapped.

During the calendar year 1935, 1,679 packages of limes were exported to the United States. These limes were generally shipped in standard-size citrus boxes, though many shipments were made in other types of containers, such as tomato crates, cucumber boxes, pepper crates, and nail kegs. Practically no attempt has been made to grade or pack limes properly. The limes were generally of nonuniform maturity and poorly sized; almost all of these shipments contained a large percentage of limes that were misshapen, showed thorn injury, or were badly scarred. The limes were not wrapped in paper and were generally loose in the packages; for that reason practically all shipments showed a high percentage of bruising and decay by the time they arrived in New York.

These limes were sold at a discount in competition with limes from the British West Indies, because of their poor condition.

There are about 30,000 lime trees in commercial groves.

Approximately 30,000 lime trees from 2 to 6 years old are growing at present in commercial groves in Puerto Rico.

The purposes of the present experimental shipments were (1) to determine the proper standard container and (2) to determine the effect of standardization, maturity, and grading upon facility of sales, and prices received.

Cucumber boxes seem well adapted for packing limes.

Standard cucumber boxes were selected whose inside dimensions were 15 inches long, 12 inches wide, and 12 inches deep. Such boxes were selected because (1) their size was such that retailers could use a whole box without repacking; (2) the capacity of these boxes was approximately one-third of a barrel, which is the standard container used in most of the other West Indian shipping sections, and standard packs can thus be made that contain approximately one-third of the contents of a barrel of the same size limes; and (3) these boxes were carried in stock by dealers and were easily obtainable.

Native seedling limes, oblong in shape, from 1⅝ to 2 inches in diameter, were used; all were hand-clipped from the trees. As regards maturity, all limes, except those in jumble pack, were fully developed, juicy, and of a dark-green color. In the jumble pack the fruit was picked following the usual practices used in the island and contained immature fruit lacking in juice as well as limes that were fully developed, and were turning yellow or were fully yellow. The limes in all boxes, except jumble pack, were carefully graded, as to shape, maturity, texture, bruises, scars, thorn scratches, cuts, and insect injury. Each wrapper was given a complete twist. Fruit was sized by eye and therefore sizing was not uniformly regular.

Jumble pack was compared with selected graded wrapped fruits in boxes.

Comparisons were made of fruits in a jumble pack, with no grading, uniformity of size, or wrapping, against limes in standard pack unwrapped, standard pack with two limes to each wrapper, and standard pack with a single lime to each wrapper. The standard pack boxes were of two sizes, 486 to the box and 650 to the box.

Limes, 486 to the box, 2 limes wrapped in a single paper, were packed 9 layers deep, 6 rows wide, and 4½ rows long. The same type of wrapping for 650 to the box were 10 layers deep, 7 and 6 rows wide, and 4½ rows long. The paper was 9 by 9 inches for the 486 size and 8 by 8 inches for the 650 size.

In the case of the standard pack, unwrapped, or each fruit wrapped separately, the limes were packed for the 486 size 9 layers deep, 9 rows long, and 6 rows wide; for the 650 size, 10 layers deep, 10 rows long, and 7 and 6 rows wide. Where the fruits were wrapped separately, the papers were 8 by 8 inches for the 486 size and 7 by 7 inches for the 650 size.

Careful packing resulted in delivery of better fruits.

Table 23 shows the methods of packing in these shipping tests, the conditions at time of arrival, and the prices received. The fruits were packed in San Juan December 3, shipped December 5, and received in New York December 10, 1935.

TABLE 23.—*Type of pack, sizes of fruits, condition on arrival, and prices received on an experimental shipment to New York of island limes of 8 different sizes and methods of wrapping and packing* [1]

Type of pack	Symbol	Size	Boxes	Limes per box	Condition of pack— After 24 hours	Condition of pack— On arrival in New York	Degree of maturity in New York	Discolorations and decays	Price per box
			No.	*No.*					*Dol.*
Jumble, no selection, grading, or wrapping.	A1	Medium	2	672	Slightly slack.	Slack	20 percent full yellow; 7 percent part yellow; 73 percent full green.	13 percent discoloration from injury to oil cells; 8 percent scald; 5 percent *Diplodia* rot.	3.75
	A2	Large	2	512	do	do			4.10
Standard pack, unwrapped.	B3	Medium	2	650	Tight [2]	Tight [2]	Firm, all good green.	7 percent injury to oil cells, no scald, no rot.	4.50
	B4	Large	1	486	do [2]	do [2]			5.25
Standard pack, wrapped 2 limes per wrapper.	C5	Medium	2	650	do [2]	do [2]	do	3 percent injury to oil cells, no scald, no rot.	5.00
	C6	Large	2	486	do [2]	do [2]			5.75
Standard pack, each lime wrapped separately.	D7	Medium	3	650	do [2]	do [2]	do	do	5.65
	D8	Large	2	486	do [2]	do [2]			6.75

[1] Experiment by Mason.
[2] 1-inch bulge.

From table 23 it can be seen that the large limes in standard pack, wrapped separately, yielded the best price per crate.

Limes were precooled and shipped under refrigeration.

All boxes were precooled for 36 hours before shipment. Temperature of limes at time of shipment was 43° F. They were loaded in a precooled hold of the ship and carried at a room temperature of be-

tween 45° and 46°. An inspection of these limes was made at San Juan 24 hours after packing because injury caused by bruising to oil cells usually will show in that period of time. The New York receiver's representatives also made a complete inspection of each lot as to arrival condition of the fruits. The results of these inspections are also recorded in table 23.

It cost 94.5 cents to pack, precool, and ship a box of limes to New York.

The detailed costs of the picking, packing, freight charges, handling, and marketing in New York, of this shipment were as follows: Box 12 cents; packing labor, 4 cents; picking labor, 6 cents; paper, 5 cents; nails, 0.5 cent; labels, 5 cents; transportation to San Juan, 6 cents; ocean freight to New York, 43 cents; trucking—New York, 10 cents; supervision, 2 cents; insurance, 1 cent; total per box, 94.5 cents.

Ten percent of the total sales price was added as the commission to the selling agency in New York.

Careful picking, grading, wrapping, and packing paid good returns.

Deducting shipping costs, which were almost uniform for all types of pack, it seemed evident that careful picking, inspection, grading, packing, wrapping, and discretion in the selection of a uniform type of box increased the return to the grower almost 100 percent.

Puerto Rican wrapped limes in standard pack brought better prices than limes from other countries.

Table 24 shows the prices received for limes from other countries on the same day that the experimental shipment from this island was sold.

TABLE 24.—*Prices received for limes from various countries on the New York market, Dec. 10, 1935* [1]

Country of origin	Type of pack and container	1,500's	1,800's	2,100's
		Dollars	*Dollars*	*Dollars*
Puerto Rico	Jumble pack, to equal 1 barrel [2]	12.10		
Do	Single wrapped, to equal 1 barrel [3]	20.25	16.95	
Jamaica	Barrel	14.00	14.00	
Dominica	do	14.50	14.50	14.00
St. Lucia	do	14.50	14.50	14.00
Jamaica	Bushel box		4.75 to 5.00	
Santo Domingo	Keg, approximately seven-eighths of a bushel		4.00	

[1] Data by Mason.
[2] In crates, 3 of which contained 1,536 limes, approximately equal to 1 barrel.
[3] In crates, 3 of which approximated the volume of 1 barrel, the large-sized limes being 1,458 in 3 crates and the medium size 1,950 in 3 crates.

It can be seen from table 24 that whereas the Puerto Rican limes in the jumble pack brought poorer prices than the limes from other West Indian islands, the well-packed limes brought considerably better prices than those from neighboring islands.

Sweet corn not iced in the field marketed poorly.

During the winter months of 1932 and 1933 several small trial shipments of sweet corn to New York were attempted from various sources. This corn was grown from seed obtained from the station. Such corn was packed but not iced on the farms, and precooled for 2 or 3 days before shipment. No ice was placed in the crates in shipment and the husks on many of the ears were turning brown before they left

San Juan. The corn was shipped under ordinary refrigerating temperatures of between 44° to 46° F. and arrived at New York in poor condition. The husks generally were brown and the kernels shrunken and doughy.

Sweet corn grown at the experiment station was shipped in January.

On January 2, 1936, nine crates of the sweet corn varieties USDA–32 and USDA–34, grown at the station, were prepared for shipment to New York. The corn was picked in the morning and immediately covered with cracked ice in the field; upon arrival in San Juan, it was repacked and graded.

The corn was packed in standard pepper crates the inside dimensions of which were 11 by 14 by 22 inches, having a cubic content of $1\frac{9}{16}$ bushels. It was packed crosswise, and inasmuch as the ears were generally 9½ to 11 inches long, there was practically no waste space next to the sides of the crates which could later cause slack.

Corn iced in the field was carefully graded and packed.

Care was used in grading the corn; only ears of reasonably uniform length were used. Care was exercised to see that the ears were properly filled, and all nubbins were discarded. Only ears showing a good fresh green color were used; all loose husks were removed. Shanks that extended more than 1 inch beyond the point of attachment of the outer husk were removed. No ears were shipped that showed worm injury extending more than 1½ inches from the tip of the cob. The kernels were all plump and milky and showed no hardening or shriveling and were apparently at the proper stage of maturity for shipping.

The crates contained from 84 to 92 ears each. Cracked ice was packed with the corn, 25 pounds being distributed throughout the nine crates. When the lids were in place, the packages had a bulge of 2½ to 3 inches. This bulge was necessary because otherwise as the ice melted, the crates would present a slack appearance. Immediately after packing the corn was placed in a special compartment on the boat which had been previously precooled to a temperature of 32° F. Approximately 25 pounds of block ice were placed over the tops of the crates. The shipping temperature was maintained from San Juan to New York at 32°. The corn arrived in New York in the same condition as it left San Juan and with practically all ice intact.

Corn arrived in New York in excellent condition.

W. C. Hackleman, regional supervisor of the Division of Fruits and Vegetables of the Bureau of Agricultural Economics, and W. H. Stanton, New York sales manager for the Puerto Rico Fruit Exchange, who handled this corn in New York, both stated that the corn was of excellent quality, comparable to the best summer sweet corn produced in New Jersey and on Long Island. They made the following comments:

(1) That the ears were smaller than those generally received during the early spring months from Florida, Alabama, and Texas, and that this defect could probably be improved by fertilizer practices. (2) That the husks did not have as attractive green color as corn that is usually received in the spring and summer New York market but that the unusual marketing period in the winter months would

offset this defect. Mr. Hackleman also stated that once the trade is assured of the fact that there would be a regular supply, a good demand could be created at once for a limited supply of this corn.

The appearance of this corn as it arrived in New York is shown in figure 16.

A similar experimental shipment of three crates of roasting ears was made on January 16 to Washington, D. C. Ears from this shipment

FIGURE 16.—A crate of USDA-34 sweet corn from an experimental shipment as it arrived in New York in January 1936. Some of the corn was shipped in cellophane as a trial.

were tested by various agronomic experts of the Department, whose statements concerning its quality were uniformly favorable, in some cases laudatory.

The packing, shipping, and marketing studies have been carried on by A. S. Mason, associate marketing specialist of the station.

SUGARCANE INVESTIGATIONS

Twelve replicated variety experiments were harvested during the year.

With the attention which has been necessary for studies of new crops and other activities connected with agricultural rehabilitation, the development of sugarcane investigations has not been as active as was

desirable. However, it is possible to record the results of several agronomic trials of new sugarcane varieties, studies of the distribution of sugarcane roots in the soil, and a very thorough review of sugarcane diseases.

During the past year 12 variety experiments have been harvested. In each of these experiments, located in various parts of the island, from 2 to 7 varieties have been compared. All plats in each experiment received identical fertilizer and cultivation practices, were planted at the same time, and harvested simultaneously. The number of replications varied from 4 in 2 experiments, 5 in 3 experiments to 6 in 6 experiments. The plats varied in size from one-eighth of an acre in some experiments to one-twentieth of an acre in others. In order to show in some detail the nature of these experiments, the results of a representative test are shown in table 25.

TABLE 25.—*Results of sugarcane variety trial at Yabucoa* [1]

[There were 6 replicated 0.1-acre plats of each variety]

Variety	Yield of cane per acre	Crusher juice analyses		Available 96° sugar per acre
		Sucrose	Purity	
	Tons	*Percent*	*Percent*	*Tons*
Mayaguez 42	80.07	15.86	87.24	9.31
P. R. 803	80.35	15.30	85.81	8.96
F. C. 916	78.17	15.06	85.32	8.53
Mayaguez 28	68.63	15.72	87.28	7.91
Mayaguez 7	65.30	15.71	85.29	7.44
P. O. J. 2878	67.20	15.19	85.29	7.40
B. H. 10 (12)	66.10	15.42	87.46	7.65

[1] Experiment by Davis and Cabrera Márquez, field superintendent at Central Yabucoa. Planted Oct. 5, 1933; harvested Feb. 15, 1935.

It will be noted from table 25 that P. R. 803 gave the greatest tonnage of cane per acre and that Mayaguez 42 gave the highest sucrose percent and the highest yield of sugar per acre. P. O. J. 2878 and B. H. 10 (12) gave comparatively low yields of cane and sugar per acre in this experiment with 16-month-old cane.

Mayaguez 63 showed a good record in yield of cane per acre.

In table 26 the yield of cane per acre for each variety is shown in the 12 variety experiments conducted during the past year.

In cane tonnage, Mayaguez 63 placed first four times and third twice out of seven trials. Mayaguez 28 was first twice, second once, and third once out of 10 trials. P. R. 807 was first once and second once out of 2 trials and deserves further experimentation. P. R. 803 was first once and third once out of 4 trials. F. C. 916 was first once, second twice, and third twice out of 6 trials. In 9 trials P. O. J. 2878 was second 4 times and did not place in the other experiments. B. H. 10 (12) was first once and second twice out of 5 trials.

Comparing the tonnage produced by Mayaguez 63 and P. O. J. 2878, a variety with previous records of high cane tonnage, it will be seen that Mayaguez 63 outyielded P. O. J. 2878 four times and was outyielded only once in the five experiments in which they were both represented.

B. H. 10 (12) made a good showing in percent sucrose.

In table 27 the percent sucrose in crusher juice for each variety in the experiments is shown.

B. H. 10 (12), ordinarily considered to be one of the canes of highest sugar content grown in Puerto Rico, was first twice and third once in 5 trials. In the 5 experiments in which B. H. 10 (12) was included with Mayaguez 28, B. H. 10 (12) had the better sucrose 3 times, the percent sucrose was identical in 1 experiment and Mayaguez 28 was better than B. H. 10 (12) once. P. O. J. 2878 was first 3 times, second twice, and third once in 9 trials. Mayaguez 28 was first once and second 6 times out of 10 trials. The results in terms of percent sucrose in the case of Mayaguez 63 do not stand out as encouragingly as the yield of cane per acre for this variety; in 7 tests Mayaguez 63 yielded first once, second once, and third once.

Mayaguez 63 showed a good record in yield of sugar per acre.

Table 28 shows yield of sugar per acre for each variety in the 12 experiments. One of the most interesting results observed was the unexpected performance by Mayaguez 63; in 7 trials Mayaguez 63 gave the highest yield of sugar per acre 4 times and second highest once. It is of interest to compare this record with B. H. 10 (12), which out of 5 trials was first once, second once, and third twice. P. O. J. 2878 was second 4 times and third once out of 9 trials. F. C. 916 was first once, second once, and third twice out of 6 trials. Mayaguez 28 was first twice, second once, and third once, out of 10 trials.

Variety trials are a valuable investment for every sugarcane grower.

The results that have been presented in tables 26–28, while admittedly not so complete or extensive as may be desired, do raise the question as to whether the highest-yielding varieties are being grown in the acreage which is warranted at the present time.

Many sugarcane growers in the island have conducted variety tests of one kind or another during recent years. In many cases these tests consisted of a comparison of two varieties, one of which was planted in one field and the other in a field nearby. Because of well-known variations in soil and drainage, tests of this kind often provide erroneous results, and in unreplicated trials no reliable information is obtained. It would seem to be a valuable investment for each extensive grower of sugarcane to conduct well-planned variety trials on several of the more important soil types on his plantation. Such a varietal trial should consist of from 4 to 6 varieties of sugarcane laid out in plats not smaller than 0.1 acre in size and replicated not less than 6 to 10 times. The information to be gained from such trials would seem, if utilized, to pay large dividends on the amount spent in conducting the tests.

The work on sugarcane agronomy during the year has been conducted by R. L. Davis, agronomist.

Distribution of sugarcane roots in the soil.

A study of the distribution of sugarcane roots in the soil, using methods similar to those described to study sweet corn roots, was completed during the year. The technique for these studies was developed in Hawaii and the Philippines, where similar studies have been carried on.

TABLE 26.—*Yield of cane per acre for each variety in 12 variety experiments conducted during the past year*

Location	Age	Date of harvest	Replications	Size of plats	Plant or ratoon	Irrigated or unirrigated	Yield of cane per acre													
							B. H. 10 (12)	P. O. J. 2878	F. C. 916	P. R. 803	P. R. 807	M-7	M-28	M-42	M-48	M-63	M-275	M-317	M-318	Miscellaneous
	Months		*Number*	*Acres*			*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Isabela	19	Mar. 27, 1935	6	1/20	Plant	Irrigated			58.05				47.75			58.99		49.81	53.34	[1] 53.29 [2] 57.51
Vega Baja	12	Mar. 28, 1935	6	1/10	do	do	42.30						36.51							
Do	12	Apr. 24, 1935	5	1/10	do	do	45.85	49.68	49.40				44.18		40.90	47.76	54.09			
Do	16	Feb. 6, 1936	6	1/10	do	do	68.80						60.88		60.18	72.98	65.41	51.62		
Añasco	17	Feb. 8, 1935	4	1/8	do	do		38.6	49.1						39.0					[3] 47.2
Mayaguez	16	Mar. 3-8, 1935	6	1/20	do	do		61.62	58.45	61.91	67.27		53.03			80.07				
Do	12	Mar. 18, 1936	6	1/20	Ratoon	do		35.30	39.35	33.32	41.67		31.45			35.88				
Humacao	16	Feb. 14, 1935	4	1 1/100	Plant	Unirrigated	63.96	60.57		59.85		59.27	69.70	61.56		63.14				
Yabucoa	16	Feb. 15, 1935	6	1/10	do	do	66.10	67.20	78.17	80.35		65.30	68.63	80.07						
Hormigueros	12	Apr. 30, 1935	5	1/20	Ratoon	do		42.15										42.36	36.88	[4] 36.34 [5] 30.90 [6] 37.14
Do	16	Jan. 22, 1935	5	1/10	Plant	do		66.96					61.88			82.21				
Do	12	Apr. 20, 1935	6	1/10	Ratoon	Irrigated		36.92					39.39							

[1] M-260. [2] M-266. [3] M-3. [4] M-103. [5] M-104. [6] M-314.

TABLE 27.—*Percent sucrose in crusher juice for each variety in 12 variety experiments, 1935–36*

Location	Age	Date of harvest	Replications	Size of plats	Plant or ratoon	Irrigated or unirrigated	Sucrose in crusher juice													
							B. H. 10 (12)	P. O. J. 2878	F. C. 916	P. R. 803	P. R. 807	M–7	M–28	M–42	M–48	M–63	M–275	M–317	M–318	Miscellaneous
	Months		*Number*	*Acres*			*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Isabela	19	Mar. 27, 1935	6	1/20	Plant	Irrigated			14.5				16.0			15.1		15.9	11.9	[1] 16.2
Vega Baja	12	Mar. 28, 1935	6	1/10	do	do	16.91						15.96							[2] 14.9
Do	12	Apr. 24, 1935	5	1/10	do	do	17.64	17.15	15.72				17.61		16.79	15.86	16.41			
Do	16	Feb. 6, 1936	6	1/10	do	do	13.43						13.07		12.59	13.12	14.16	14.07		
Añasco	17	Feb. 8, 1935	4	1/8	do	do		15.5	15.7						16.3					[3] 16.0
Mayaguez	16	Mar. 3–8, 1935	6	1/20	do	do		16.74	13.08	14.73	12.88		14.57			15.55				
Do	12	Mar. 18, 1936	6	1/20	Ratoon	do		14.41	13.83	12.49	13.37		13.89			13.42				
Humacao	16	Feb. 14, 1935	4	1 1/100	Plant	Unirrigated	14.87	15.33		15.33		14.99	14.87	14.71		15.36				
Yabucoa	16	Feb. 15, 1935	6	1/10	do	do	15.42	15.19	15.06	15.30		15.71	15.72	[4] 15.86						
Hormigueros	12	Apr. 30, 1935	5	1/20	Ratoon	do		12.5										14.2	16.6	[4] 14.7 [5] 15.5 [6] 17.1
Do	16	Jan. 22, 1935	5	1/10	Plant	do		14.9					14.3			12.9				
Do	12	Apr. 20, 1935	6	1/10	Ratoon	Irrigated		16.0					17.8							

[1] M–260. [2] M–266. [3] M–3. [4] M–103. [5] M–104. [6] M–314.

TABLE 28.—*Yield of sugar per acre for each variety in the 12 variety experiments, 1935–36*

Location	Age	Date of harvest	Replications	Size of plats	Plant or ratoon	Irrigated or unirrigated	Yield of sugar per acre													
							B. H. 10 (12)	P. O. J. 2878	F. C. 916	P. R. 803	P. R. 807	M–7	M–28	M–42	M–48	M–63	M–275	M–317	M–318	Miscellaneous
	Months		*Number*	*Acres*			*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Isabela	19	Mar. 27, 1935	6	1/20	Plant	Irrigated			6.35				5.69			6.79		6.16	4.63	[1] 6.72 [2] 6.52
Vega Baja	12	Mar. 28, 1935	6	1/10	do	do	5.54						4.49							
Do	12	Apr. 24, 1935	5	1/10	do	do	6.34	6.52	5.96				6.10		5.34	5.85	6.77			
Do	16	Feb. 6, 1936	6	1/10	do	do	9.28						7.94		7.58	9.54	9.24	7.27		
Añasco	17	Feb. 8, 1935	4	1/8	do	do		4.63	6.00						4.95					[3] 5.88
Mayaguez	16	Mar. 3–8, 1935	6	1/20	do	do		8.07	5.67	7.11	6.20		6.08			9.84				
Do	12	Mar. 18, 1936	6	1/20	Ratoon	do		5.31	5.46	4.15	5.61		4.36			4.79				
Humacao	16	Feb. 14, 1935	4	1/100	Plant	Unirrigated	6.80	6.60		6.64		6.32	7.44	6.47		6.95				
Yabucoa	16	Feb. 15, 1935	6	1/10	do	do	7.65	7.40	8.53	8.96		7.44	7.91	9.31						
Hormigueros	12	Apr. 30, 1935	5	1/20	Ratoon	do		3.81										4.55	4.72	[4] 4.01 [5] 3.69 [6] 4.96
Do	16	Jan. 22, 1935	5	1/10	Plant	do		7.56					6.80			7.88				
Do	12	Apr. 20, 1935	6	1/10	Ratoon	Irrigated		4.45					5.51							

[1] M–260. [2] M–266. [3] M–3. [4] M–103. [5] M–104. [6] M–314.

The studies at the station were carried on in clay soils on mature 12-month-old cane of P. O. J. 2878 first ratoons. The studies showed 64 percent of the roots in the topmost 8-inch layer of soil, 15 percent in the layer from 8 to 16 inches in depth, and but 21 percent in the layers below the sixteenth inch. The foregoing findings correspond rather closely to the results obtained from studies of root distribution in Hawaii and the Philippines. The results indicate that tillage, irrigation, drainage, fertilization, and cultivation should be carried on with the understanding that a large majority of roots of the sugarcane plant are comparatively near the surface.

This work was carried on by Luis A. Gomez, scientific aide.

Mosaic the most important disease of sugarcane in Puerto Rico.

During the year a survey of sugarcane diseases in the island was undertaken and the results published in Agricultural Notes, no. 69, of the Puerto Rico Experiment Station.

Sugarcane mosaic was found present throughout all districts. This disease, while the most serious on sugarcane at present, was found in most instances to be successfully controlled either by the use of resistant varieties or the periodic removal of diseased plants. Evidence was obtained that two or more strains of sugarcane mosaic virus occur in Puerto Rico. The leaf spot diseases, ring spot, brown stripe, and eyespot, were found in all sections of the island, but no serious losses were caused by these diseases this year. Dry rot, *Fusarium* pokkah boeng, red stripe, and red rot were observed present but not causing serious damage. Considerable damage due to what is believed to be a manganese deficiency was found along the south coast. No sugarcane diseases new to Puerto Rico were found.

The work on sugarcane diseases was carried on during the year by James H. Jensen, pathologist.

PLANT-DISEASE INVESTIGATIONS

Corn stripe, a virus disease, has not been reported in the continental United States.

Corn stripe, a destructive virus disease of corn, transmitted by a leafhopper, *Peregrinus maidis*, occurs in Puerto Rico and in a number of other tropical countries. This disease has not been reported from the continental United States, although the insect vector is known to occur there.

In order that methods of preventing the establishment of this disease in the continental United States would be well understood the following experiment testing seed transmission was undertaken. Seeds from ears taken from both diseased and healthy plants were planted in separate plats in an insect-proof cage, screened to exclude the insect vector, *Peregrinus maidis*, of corn stripe. Identical lots of seed from ears from both diseased and healthy plants were coincidently planted in unscreened areas where they were exposed to infestation by the leafhopper vector of the disease. Table 29 shows the subsequent incidence of corn stripe disease in the two lots of plants in the insect-proof cage as compared with the disease counts in the plants exposed to infestation by the leafhopper.

TABLE 29.—*Diseased corn plants which developed from seed from healthy plants and seed from diseased plants grown in insect-proof cage as compared with plants from identical lots of seed exposed to the corn stripe disease vector*

Origin of seed	Planted in insect-proof cage				Planted exposed to insect vector			
	Plants	Diseased after—			Plants	Diseased after—		
		32 days	41 days	72 days		32 days	41 days	72 days
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Diseased plants	1,952	0	0	0	583	9	20	30
Healthy plants	973	0	0	0	511	8	38	51

Seed from diseased corn plants did not transmit corn stripe.

Table 29 shows that no disease symptoms appeared on any plants grown from seed from diseased plants when such plants were protected from visitation of the leafhopper vector, whereas from the same lot of seed 30 plants became diseased when grown unprotected. Similar results were obtained when seed from healthy plants was used. No disease appeared in any plants from seed from healthy plants when grown in an insect-proof cage, whereas 51 plants grown from the same lot of seed became diseased when planted unprotected from visitations of the insect vector. The results of this preliminary experiment indicate that seed transmission of corn stripe rarely, if ever, occurs.

Plant-quarantine house was constructed.

A plant-quarantine house especially designed to aid in the controlled introduction of new economic plants into Puerto Rico was constructed during the year. This plant-quarantine house, 17 by 24 feet in size, has its foundation and the lower part of the side walls of concrete. The walls above the concrete are screened with 30-mesh copper wire netting. The roof of the house is covered with a glass-cloth material. The house is surrounded by a concrete trough which when filled with water constitutes a water moat 7 inches wide. The entrance into the quarantine house consists of an antechamber divided into two compartments having three tightly closing doors. The antechamber is of wooden construction, lightproof, and painted black inside to discourage the entrance of phototropic insects. The inside plant benches are of concrete and steel construction because wood decay progresses rapidly in the Tropics.

The quarantine house has been inspected and approved by the plant-quarantine inspector of the Bureau of Entomology and Plant Quarantine and by the quarantine service of the Insular Department of Agriculture and Commerce. Plants of several kinds, including sugarcane, grasses, cotton, and palms, have already been successfully introduced into the island by means of the quarantine house, with assurance that no new diseases or insect pests have coincidently been imported. This quarantine-detention house is also being used by other agencies of the Federal and Insular Governments.

Insect-proof house for study of virus diseases constructed.

A second plant house of the same dimensions as those of the plant-quarantine house was built for use in connection with studies of virus

diseases of plants. Instead of an antechamber entrance, however, the house is equipped with a headhouse with plant-potting benches, and provisions for storage of tools, washing of pots, and similar uses.

Figure 17 shows the two plant houses described above. Plant-disease investigations during the year were conducted by James H. Jensen, pathologist.

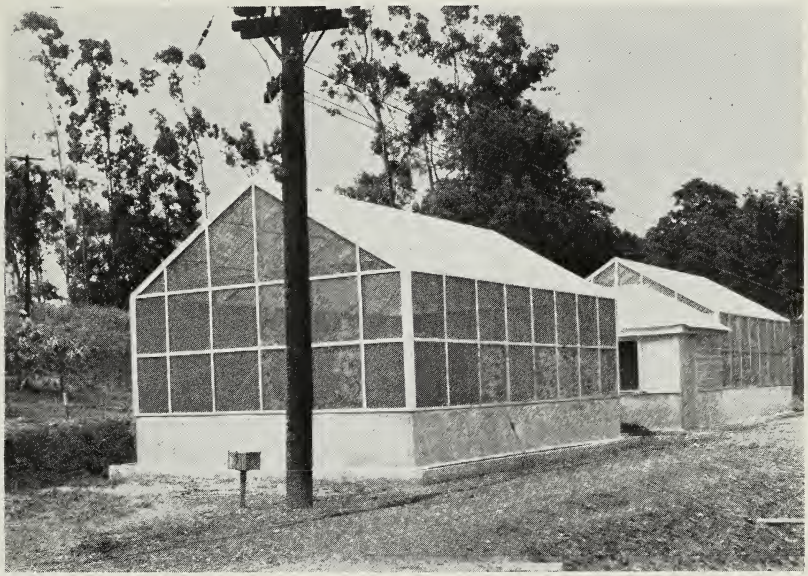

FIGURE 17.—Two plant houses constructed by the division of plant pathology; in the foreground is the plant-quarantine detention house, and to the rear is the house used in the study of virus diseases of plants.

COFFEE INVESTIGATIONS

Cooperative work of experiment stations continued successfully.

In the last annual report mention was made of the organization of a coffee research center located at the station, in the midst of the coffee district, in which the respective experiment stations of the College of Agriculture of the University of Puerto Rico and the United States Department of Agriculture cooperated. This cooperation has continued successfully throughout the year.

Jaime Guiscafré-Arrillaga of the University of Puerto Rico Experiment Station has continued in active charge of this cooperative work. During the year the university station found it possible to appoint Ventura Barnes, Jr., as an assistant to the coffee specialist for duty at the coffee research center, effective November 1, 1935.

During the year a new office and laboratory building was conditioned for use in the coffee work. This building includes equipment for depulping and drying the fresh berries, and, being nearer to the coffee orchards, contributes to the greater efficiency with which the personnel can maintain their activities.

Experiment station has representative collection of coffee species and varieties.

For a number of years under the leadership of T. B. McClelland, this station built up an extensive collection of species of coffee and varieties of *Coffea arabica*. The trees in this collection are now mature, and field charts of their locations have been prepared and blue printed. At present the collection contains the following species of *Coffea* and varieties of *C. arabica: Coffea arabica* varieties Blue Mountain, Bourbon, Columnaris, Erecta, Guadeloupe, Java Mocha, Le Roy, Maragogipe, Mocha, Murta, Padang, Philipinean, Preanger, Santo Domingo, San Ramón, Sumatra, Surinam, Ceylon hybrid, and Marasan hybrid; *C. abeokutae*, *C. arnoldiana*, *C. canephora*, *C. congensis*, *C. congensis* var. *chalothii*, *C. dewevrei*, *C. dybowskii*, *C. excelsa*, *C. liberica*, *C. robusta*, *C. robusta* var. *quillou*, *C. sankuruensis*, and *C. ugandae hybrid;* and *Posoqueria latifolia*.

New experiments with coffee were inaugurated.

Several new experiments were undertaken under the foregoing cooperative arrangement. In one of these, coffee grown in full sunlight was tested against coffee grown in two-thirds, one-half, and one-third sunlight, respectively. There were four replicated plats of each degree of shade, which was furnished by wooden lath coverings.

In another experiment, six species of leguminous trees were tested as shade for coffee, and there were six replicated plats for each shade-tree species.

A third experiment undertaken compared four different systems of pruning coffee trees, in which there were 10 replicated plats for each type of pruning. All of these experiments were placed on Catalina clay, the soil type most prevalent in the coffee-growing districts of the island.

Coffee grown in Puerto Rico was originally introduced from Santo Domingo.

Arabian coffee, *Coffea arabica*, is grown in Puerto Rico almost to the exclusion of all other species and varieties. History indicates that this coffee was originally introduced from the neighboring island of Santo Domingo, and for this reason it is referred to from time to time as the Santo Domingo variety. More recently the station introduced from Java what is called the Columnaris variety; this is also a variety of *C. arabica* with the same desirable flavor and aroma and advantages for marketing possessed by the Santo Domingo variety.

Columnaris variety significantly outyielded the Santo Domingo variety.

A replicated test of these two varieties of Arabian coffee was inaugurated by T. B. McClelland in 1931. The harvesting results secured in this test during 1935 with similar results for 1934 are shown in table 30. The experiment consisted of seven plats of each variety, each plat having one row of six to eight trees. The soil was homogeneous fairly uniformly sloping, and classed as Catalina clay. The shade tree used was *Erythrina berteroana*, known locally as "machete" or "bucare enano", and it was uniformly planted throughout the plats.

TABLE 30.—*Comparison of yields obtained from plats of the Columnaris and Santo Domingo varieties of coffee at Mayaguez, 1934–35* [1]

Variety	Trees	Fresh berries						Marketable coffee per acre	
		1934 crop			1935 crop				
		Per experiment	Per tree	Per acre	Per experiment	Per tree	Per acre	1934 crop	1935 crop
	Number	*Kg*	*Kg*	*Kg*	*Kg*	*Kg*	*Kg*	*Lb.*	*Lb.*
Columnaris	50	61. 69	1. 234	771. 25	185. 49	3. 70	2, 312. 50	373. 28	1, 119. 25
Santo Domingo	50	61. 54	1. 230	768. 75	102. 27	2. 04	1, 275. 00	372. 07	617. 00

[1] Experiment by McClelland, Guiscafré, Lee, and Esteva.

It can be seen that in the 1934 crop the yields of both varieties were of practically identical quantities as well as quality.

In 1935, however, the Columnaris variety outyielded the Santo Domingo variety by 81 percent. The harvest results have been examined statistically and the experimental differences shown above can be considered highly significant.

The Columnaris trees are definitely larger and more vigorous than the trees of the Santo Domingo variety. The results of subsequent crops in this experiment will be watched with great interest. In the meantime the evidence to date would indicate that the Columnaris variety of coffee may offer aid in rehabilitating the coffee industry of western Puerto Rico.

The Columnaris variety of *Coffea arabica* should not be confused with *C. excelsa;* the latter species has inferior flavor and aroma and sells in the world's markets for considerably less than ordinary Arabian coffee. There is no reason to believe that the Columnaris will sell for any less than the Santo Domingo variety, which now constitutes more than 99 percent of the Puerto Rican crop.

Reduction of shading increased coffee yields.

Another experiment started by T. B. McClelland in 1931 comprised the growing of trees from the same clone of *Coffea arabica* in similar soil but with varying degrees of sunlight. Eight of the trees were grown in full sunlight, eight were grown in a lath house with the normal light reduced to one-half, and eight were grown in a lath house which reduced the normal light to one-third. The plats of the different degrees of sunlight were not replicated, but they were contiguous, and the soil was mixed together, which would eliminate the effect of soil heterogeneity on the results. The yields in this experiment for the 1933, 1934, and 1935 crops are listed in table 31.

TABLE 31.—*Yields of coffee obtained from trees exposed to various degrees of sunlight at Mayaguez, 1933–35* [1]

Treatment	Average yield per tree		
	1933 crop	1934 crop	1935 crop
	Kilograms	*Kilograms*	*Kilograms*
Trees grown in one-third normal sunlight	0. 105	0. 709	1. 100
Trees grown in one-half normal sunlight	. 280	1. 361	2 251
Trees grown in full sunlight	. 105	2. 722	2 543

[1] Experiment by McClelland, Guiscafré, and Lee

The trees grown in full sunlight during the last 2 years gave by far the largest yields per tree. Those in one-half normal sunlight greatly outyielded the trees grown in one-third normal sunlight. Although the unshaded trees have greatly outyielded the shaded trees during the last 2 years, the unshaded trees do not now appear thrifty, and a casual observer unacquainted with the yields would select the shaded trees as being the best producers. In this experiment there was also some evidence to indicate that the trees required more shade when young and less as they matured.

The conclusion to date would be that some of the coffee orchards of the island have employed too much shade to give the maximum coffee yields, but the poor appearance and lack of vegetative vigor of the unshaded trees would confirm the practice that some degree of shade is necessary to maintain the trees in a healthy condition.

INVESTIGATIONS OF INSECTICIDAL PLANTS

Fish-poison plants furnish insecticides harmless to man and domestic animals.

In an effort to obtain insecticidal materials harmless to human beings and domestic animals the attention of the Department of Agriculture has been directed in the last few years to the so-called fish-poison plants that grow wild in some of the tropical countries where they have been used to catch fish.

These fish-poison plants form a large and taxonomically heterogeneous group. The only members of this group that are now of major commercial importance as sources of insecticides are a few species belonging to the family Fabaceae, *Derris elliptica, D. malaccensis,* and *Lonchocarpus nicou.* Powders and extracts of their roots contain rotenone and chemically related compounds which are valuable as insecticides.

Investigation of insecticidal plants in cooperation with Bureau of Plant Industry.

In order to organize and initiate a study of these insecticidal plants the Bureau of Plant Industry and the experiment station have entered into a cooperative agreement during the past year. Under this agreement the Division of Plant Exploration and Introduction of the Bureau secured all available species of plants of possible value as insecticides and will continue the search for additional such plants. As most of these plants are indigenous to the Tropics, specimens of all such introductions obtained during the year were sent to the station, a tropical outpost of the Department of Agriculture. Here the plants were propagated, given a preliminary colorimetric test for content of rotenone and allied compounds, harvested, and sent to the Bureau for detailed toxicological research. For this research the Bureau completed arrangements for the grinding and extraction of plant materials and with the Bureau of Entomology and Plant Quarantine for biological tests of plants shown to have probable value as insecticides. A further objective outlined in the agreement was the carrying out by the station of a program of agronomic tests and of selection and breeding to improve the species shown in such investigations to have a probable commercial value for the production of insecticides.

As an indication of commercial interest in these insecticidal plants, it may be noted that exports of *Derris* root from the Malayan Archi-

pelago, the present chief source, have increased from 98 tons valued at $53,633 in 1931 to 642 tons valued at $287,795 in 1933.

Since the demand for rotenone-containing insecticides has been rapidly increasing, the development in Puerto Rico of crops producing such insecticides will not only be a service rendered to users of insecticides in the continental United States, but also should constitute a new and profitable source of income for the island. As there is no tariff protection at present for products of this sort, Puerto Rico must depend upon advantages gained from research to meet the competition of other tropical countries where *Derris* and *Lonchocarpus* are now being grown on a commercial scale.

One hundred and sixty insecticidal species have been introduced.

One hundred and sixty separate introductions of insecticidal plants now established and growing in the station fields, or under propagation, were received during the year from the Bureau of Plant Industry. A few additional species were secured in Puerto Rico and from neighboring islands.

Eight species have given positive reaction to the Durham tests for rotenone.

The colorimetric method known as the Durham test is a rapid and reliable means of determining the presence of rotenone and certain related compounds. This test was used in a preliminary way on many of the introduced fish-poison plants propagated at this station. The reagents for the test were applied directly to freshly cut tissues of 29 introductions and 18 indigenous species of fish-poison plants. Of the 47 kinds of plants tested the following 8 species were positive to the test: *Tephrosia candida*, *T. cinerea*, *T. noctiflora*, 5 strains of *T. toxicaria*, a species of *Tephrosia* from the Dominican Republic, 2 varieties of *Derris elliptica*,[3] *Lonchocarpus nicou*, and *Aeschynomene sensitiva*. The seeds of *Aeschynomene sensitiva* and of all species of *Tephrosia* tested gave a positive reaction. The roots of *Lonchocarpus nicou*, of the 2 varieties of *Derris elliptica*, and the 5 strains of *Tephrosia toxicaria* were strongly positive to the test.

On the basis of the above results and of the growth response of the plants to local environment, only *Derris elliptica* and *Tephrosia toxicaria* have shown promise of becoming commercially important in Puerto Rico. Most of the plants of *Lonchocarpus nicou* have not been established long enough to permit appraisal of their probable worth. However, the possibility must not be overlooked that some of the fish-poison plants being investigated may produce toxic compounds chemically dissimilar to rotenone, and give no reaction to the Durham test, but may still be valuable as insecticides.

Drying and baling plant material for tests by collaborators.

Whenever possible plants were not prepared for toxicological studies until they came into fruit. At that stage of maturity they were separated into easily divisible components such as roots, stems, and leaves, and then dried, coarsely ground, and made into small well-bound bales in a hydraulic press. Bales weighing from 4 ounces to about 1 pound each were prepared. In every case one bale was sent to Washington for determination of insecticidal value and the desired chemical analyses; when sufficient dried tissue was available,

[3] The varieties of *Derris elliptica* propagated and tested were Sarawak Creeping and Changi no. 3.

another bale was prepared and retained as a reserve at this station. Sixty-four such bales representing eighteen introductions or indigenous species have been forwarded to Washington.

Certain insects attack Derris and Tephrosia.

During the propagation of the foregoing fish-poison plants, one species of *Derris* and two of *Tephrosia* were found to be attacked by the larvae of several lepidopterous insects. These were referred to H. K. Plank of the Bureau of Entomology and Plant Quarantine in Mayaguez, who reared the immature specimens to the adult stage and submitted them for determination. The determinations shown in table 32, which follows, were made by W. Schaus, A. Busck, and C. Heinrich of the same Bureau.

TABLE 32.—*Insects found to attack fish-poison plants at the experiment station, Mayaguez, Puerto Rico, 1935–36*

Host plant	Insect	Family	Determined by—
Derris elliptica	*Lamprosema indicata*	Pyralidae	W. Schaus.
Do	*Proteides pedro*	Hesperiidae	Do.
Tephrosia candida	*Brachyachma palpigera*	Gelechiidae	A. Busck.
Tephrosia toxicaria	do	do	Do.
Do	*Etiella zinckenella*	Pyralidae	C. Heinrich.

Both species of insects attacking *Derris elliptica* were found feeding on the leaves. Those infesting the *Tephrosia* species were pod borers.

Reporting for duty on December 16, 1935, Rufus H. Moore has been in charge of the studies of insecticidal plants at the station.

ANIMAL PARASITOLOGY

Sunlight in Puerto Rico is destructive to eggs and larval stages of parasitic nematodes.

As a result of work by parasitologists, it is known that sunlight and drying are very destructive to the eggs of animal parasites. At this station during the past year the effect of sunlight on the eggs of parasites was studied in such a way that drying as a factor was eliminated. The eggs were taken directly from the ovaries of the worms and placed in watch glasses or Petri dishes filled with water. The eggs of the ascarid of the pig, which are among the most resistant to chemicals and to freezing and drying, were found to be destroyed in water in less than 5 hours by exposure to the direct rays of the sun. An exposure of 4 hours destroyed over 90 percent of the ova, and none survived 5 hours' exposure on repeated trials. The lethal effect of the sun was determined by the failure of the larvae to develop as compared with unexposed ova in water taken from the same worms and used as checks or controls. The exposures to the sun were made during the winter months.

In work with several other parasites, the ova and freshly hatched larvae of the stomach worms, *Haemonchus contortus* and *H. similis*, were destroyed in less than 2 hours under the same conditions. Some ova, such as those of the nodular worm, *Oesophagostomum columbianum*, do not develop satisfactorily in water. However, by allowing them to develop in cultures and by removing and placing the freshly hatched larvae in water, it was found that they were destroyed after an ex-

posure of 2 hours to the sun. Unexposed, freshly hatched larvae from the same culture, placed in water, remained alive and active. On the other hand, the larvae of the strongyles that are found in the large intestine of the horse, which had reached the infective stage of development, did not seem to be affected by direct sunlight in an exposure of 10 hours.

A piece of glass, placed several inches above the exposed receptacle containing the eggs, lengthened by an hour or more the time necessary to destroy the ova. The glass, which excluded a large proportion of the ultraviolet rays of the sun, was ordinary window glass having a bluish tinge.

In contradistinction to freezing temperatures of the temperate climates, the temperatures in protected or shaded areas in most parts of the Tropics are favorable throughout the year for the development of parasites. Thus the utilization of direct sunlight to minimize parasitic infestations in the Tropics should receive consideration in the construction of shelters and the arrangement of yards, corrals, and pastures for livestock.

Yaragua grass did not control worm parasites.

Previous experiments in the laboratory at Mayaguez have shown that the fine hairs and sticky exudation characteristic of yaragua grass, *Melinis minutiflora*, hinder the seed tick from climbing upon the plant and thus act as a deterrent in its spread. It seemed feasible that the same factors might prevent the larvae of worm parasites from crawling up the stalks and blades and thus that this grass might also be of value in helping to control internal parasites. The spread of many species of worm parasites is facilitated by the ability of the infective larvae to infest the grass when it is wet with rain or dew.

As they were more readily available, the larvae of the horse strongyles were used in experiments to determine the possible influence of yaragua grass in the control of parasites. The larvae of the stomach worm, *Haemonchus contortus*, were used to check the results inasmuch as the climbing ability of the larvae of this species is well known. In a series of trials it was found that the larvae of the horse strongyles, as well as the stomach worms, ascended the stalks and leaves of the yaragua grass more readily than those of malojillo grass, *Panicum purpurascens*, and other grasses. It is possible that the fine hairs on the yaragua grass provided traction for the larvae, but the most feasible explanation seems to be that yaragua grass by reason of the hairs and sticky exudation retained more moisture over a longer period than malojillo and other grasses.

However, because malojillo grass usually grows under moist or swampy conditions favorable for worm parasites, it is actually more likely to harbor such parasites than yaragua or other grasses that do not naturally grow under such conditions. This was determined several years ago and mentioned in former reports of the experiment station.

The common frog and garden snake are intermediate hosts of a tapeworm of dogs and cats.

During the year the life history of the tapeworm, *Diphyllobothrium mansoni*, of dogs and cats in Puerto Rico was determined. The first intermediate host of this tapeworm is a copepod which was identified by R. E. Coker of the United States National Museum as *Cyclops varicans* G. O. Sars. This copepod is very abundant in fresh-water pools, ditches, and sluggish streams.

After conducting feeding experiments to the final host, it was found that the second intermediate hosts were the common or white-lipped frog, *Leptodactylus albilabris*, and the garden snake, *Leimadophis stahli*. Either one or the other, or perhaps both, of these hosts are often eaten by cats or dogs, judging from the large percentage of these animals found infested with the adult tapeworms.

Lungworm in cats is widespread.

The cat lungworm, *Aelurostrongylus abstrusus*, has been found in more than 50 percent of the cats examined in Puerto Rico. Cameron [4] reported that the larvae of the worms which pass out with the feces must be ingested by mice in the muscles and subcutaneous tissues of which the larvae reach the infective encysted form. Recently M. and A. Hobmaier reported that the larvae must be ingested by snails or slugs in order to develop into the infective state.[5]

A study has been made of the life history of this worm to check on the apparent differences in these findings. It was found that several species of terrestrial snails were readily infested with the larvae of this parasite. The snail, *Subulina octona*, which harbored the infective stage of the parasite, was used in feeding experiments.

Adult lungworms were recovered on autopsy from experimental cats that were fed on infected snails. The same results were obtained when cats were fed on mice caught in the station buildings. The infective stage of the parasite was found in the muscles of the hind legs of the mice. However, attempts were unsuccessful to infect mice with the larvae as they were passed in cat feces. Apparently the mice eat infected snails and the parasite larvae, instead of passing to the lungs as in the cat, eventually reach the muscles where they become encysted. Thus the cat picks up natural infections by eating either infested mice or snails, or both.

Numerous parasites infest dogs and cats.

A study begun some years ago of the parasites of the dog and cat was continued during the past year, and additional species were encountered. E. W. Price in 1935 made a survey of the internal parasites. Table 33 lists both the external and internal parasites that were found in these animals.

TABLE 33.—*Species of parasites found in dogs and cats in Puerto Rico*

Parasite	Host	Location in host	Parasite	Host	Location in host
Arthropods:			Cestodes:		
Demodex canis	Dog	Skin.	*Taenia taeniaeformis*	Cat	Intestine.
Sarcoptes canis	do	Do.	*Taenia hydatigena*	Dog	Do.
Notoedres cati	Cat	Do.	*Dipylidium caninum*	do	Do.
Otodectes cynotis	Dog	Ear.	*Diphyllobothrium* (?) *mansoni*.	Dog and cat.	Do.
Rhipicephalus sanguineus	do	Skin.	Nematodes:		
Ctenocephalus canis	Dog and cat.	Do.	*Ancylostoma caninum*	do	Do.
Ctenocephalus felis	do	Do.	*Ancylostoma braziliense*	do	Do.
Heterodoxus longitarsus	Dog	Do.	*Toxocara canis*	Dog	Do.
Felicola subrostrata	Cat	Do.	*Toxocara mystax*	Cat	Do.
Protozoa:			*Trichuris vulpis*	Dog	Do.
Isospora felis	Cat and dog.	Intestine.	*Aelurostrongylus abstrusus*	Cat	Lung.
Piroplasma canis	Dog	Blood.	*Capillaria plica*	do	Bladder.
Trematodes:			*Dirofilaria immitis*	Dog	Heart.
Platynosomum concianum	Cat	Liver.	*Physaloptera praeputialis*	Cat	Stomach.
			Acanthocephala sp.	Dog	Intestine.

[4] CAMERON, T. W. M. OBSERVATIONS ON THE LIFE HISTORY OF *Aelurostrongylus abstrusus* RAILLIET, THE LUNGWORM IN CAT. Jour. Helminthol. 5: 55–66. 1927.

[5] HOBMAIER, M., and HOBMAIER, A. MAMMALIAN PHASE OF THE LUNGWORM *Aelurostrongylus abstrusus* IN THE CAT. Jour. Amer. Vet. Med. Assoc. (n. s.) 40 : 191–198, illus. 1935.

In dogs the hookworms, ascarids, tapeworms, mange, and ticks were among the most serious parasites. In cats, the ascarids, lungworm, tapeworms, and mange were most important. A contributing factor to the heavy parasite population appeared to be the large number of stray dogs roaming at large and carrying and spreading parasites.

Brilliant green dye was effective as a taenicide but toxic to poultry.

In collaboration with W. H. Wright, critical tests with various dyes as anthelmintics for chickens were tried. Of these, brilliant green was 100 percent efficient in the removal of *Raillietina* spp., in the eight birds tested. However, as this drug was markedly toxic to the birds, further work is necessary to find an effective, nontoxic dose rate or some means of reducing its toxicity. At the present time there is no known effective treatment for the removal of any species of tapeworm from poultry.

In other anthelmintic experiments involving cats and dogs, it was found that arecoline hydrobromide was ineffective in removing the tapeworm, *Diphyllobothrium mansoni*, where oleoresin of male fern was 100 percent effective.

Poultry parasites are common and important.

A study was made of a flock of 44 adult chickens heavily infested with parasites. These birds were used in anthelmintic experiments, and in conducting autopsies in relation with the experiments it was possible to obtain records of the intestinal parasites. The findings are given in table 34.

TABLE 34.—*Variety, incidence, and intensity of infestation by intestinal parasites in a flock of 44 adult chickens at Mayaguez, Puerto Rico, 1935*

Parasite	Location of infestation	Birds infested	Intensity of infestation
		Number	
Trematodes:			
Harmostomum commutatum	Ceca	12	Light.
Cestodes:			
Hymenolepis cantaniana	Small intestine	17	Very heavy.
Davainea proglottina	do	30	Heavy.
Amoebotaenia sphenoides	do	30	Do.
Raillietina tetragona	do	22	Moderate.
Raillietina sp.	do	6	Light.
Nematodes:			
Tetrameres americana	Proventriculus	23	Moderate.
Cheilospirura hamulosa	Ventriculus	16	Do.
Strongyloides avium	Small intestine	37	Very heavy.
Capillaria annulata	Crop	17	Moderate.
Capillaria retusa	Ceca	20	Do.
Capillaria sp.	Small intestine	21	Do.
Ascaridia galli	do	15	Heavy.
Heterakis gallinae	Ceca	18	Light.

Despite the fact that all birds in the original flock from which these chickens came had received a balanced ration, many of them had died from heavy infestations of parasites. Chiefly for the same reason, most of the remaining 44 birds used in this study were in poor physical condition.

The birds were confined in roomy yards located on a slope of heavy clay soil densely shaded by trees. The moisture retained by the soil combined with the shade evidently provided very favorable conditions for the propagation of parasites. The infestations shown here are characteristic of parasitic infestations in general in that conditions favorable for one species of parasite are usually favorable for others.

The small tapeworm, Hymenolepis cantaniana, was found abundantly in island chickens.

The comparatively small tapeworm, *Hymenolepis cantaniana*, is probably the most abundant of the tapeworms attacking chickens in Puerto Rico. The dung beetles, *Ataenius stercorator* and *A. cognatus*, are intermediate hosts of this tapeworm. Groups of chicks which were artificially hatched and maintained free of natural infestations were fed beetles infected with this tapeworm to determine the effect of the worm on the birds.

In one group which became lightly infested no ill effects could be detected by physical examination or by comparing the weights with those of uninfested birds used as checks or controls. In another group which were fed a large number of infested beetles it was found that certain birds were unthrifty and more subject than others to feather pulling and cloaca picking, although the majority made normal growth as compared with the controls. Diarrhea was not noticed among the heavily infested birds. Examinations of the mucosa of the small intestines showed, however, that the worms caused considerable irritation.

The resistance to infection and to the effects of infestation seemed to vary greatly among different individuals.

Infectious diseases of poultry.

In connection with the foregoing study of parasitic diseases of poultry, opportunity was afforded to observe and study the infectious and contagious diseases that are causing losses in this industry. The most serious diseases seemed to be pox, moquillo, and fowl cholera. Several other infectious diseases were encountered, but they seemed to be less important than the three mentioned.

Pox as usually observed here may be termed chick pox to differentiate it from the form which occurs on the continent called fowl pox. Chicks of about 2 weeks of age were attacked, and the mortality among these young birds was often found to be high. Vaccination of day-old chicks against this disease with commercial vaccines was not successful. It is possible, however, that a vaccine prepared from a local strain of virus would prove more satisfactory.

Moquillo was found to be a disease of older birds with a combination of symptoms resembling those of the disease known as roup. The term as used would probably include several diseases or diseased conditions, such as colds, roup, and pox, which occasionally occur in old birds. At times, moquillo seemed to be caused by pollen irritating the mucous membranes of the head followed by infections with bacteria.

Fowl cholera appeared to show symptoms and manifestations similar to those found on the continent. The organism producing the disease was found and seemed to be involved in many sporadic mortalities among adult birds. Peritonitis was the principal condition encountered on necropsy.

No intermediate host of the cattle tapeworm was found.

Attempts were continued to find the intermediate host of the cattle tapeworm, *Moniezia expansa*. Repeated trials to infect copepods with the eggs of the tapeworm were unsuccessful. The copepods which probably included several species of *Cyclops* were obtained from

the fresh water of pools and ditches in various localities of the island. The eggs were taken from the fresh segments of tapeworms or were sieved from the fresh feces of infested animals. When fresh material was provided every few days the copepods fed readily on the ova of the tapeworm and subsisted for several weeks on this food without, however, becoming infested.

Malojillo grass favors liver fluke infestation in cattle.

A general survey of the distribution of the liver fluke, *Fasciola hepatica*, a parasite of cattle, goats, and swine, was completed in September 1935. This parasite was found to be widely distributed over the island except in the dry southern coastal plain, where marshes are limited in extent. In these dry sections the snail, *Lymnea cubensis*, which transmits the fluke, was found only in limited areas around watering troughs and windmill pumps where there is more or less constant overflow of water. Animal infestation by the fluke in these areas was therefore slight. On the other hand, environmental conditions in the valleys of the higher, more humid mountain districts were often favorable for the snail. On the whole, the fluke was found more commonly in herds that were pastured or fed on malojillo rather than on other grasses. Conditions most favorable for this grass are also favorable for the snail. A large percentage of the cows in all the larger dairies in Mayaguez and vicinity were found to be infested with this fluke.

A manure bag for study of internal parasites of the goat.

It has usually been difficult to raise and maintain goats in the wet coastal areas of Puerto Rico because of the abundance and seriousness of internal parasites. As practically all of the eggs and larvae of these parasites pass out in the manure, a cloth bag attached to goats to collect and hold the manure as it is passed was tried as a control measure for the parasites. This manure bag was supported by a harness arrangement and attached at all times while the goat was staked out or in pasture.

The principal disadvantage found was the danger of the washing of the ova through the manure onto the ground during heavy rains. However, this difficulty was overcome by providing shelter for the animal during all showers. When the bag was properly made there was little danger of the ova being washed through the cloth by the urine in the case of a female goat because of the manner of micturation. To be successful as a control measure for parasites, daily attention was necessary to collect and properly dispose of the manure in order to prevent contamination of fields and pastures. Although this control measure yielded practical results, it is recommended only to the owner to whom a milk goat is a valuable animal and who manages it as such.

Toad venom was extracted and dried for experimental purposes.

The experiment station cooperated with the School of Medicine of the Johns Hopkins University during the past year in procuring a considerable quantity of venom from toads for experimental purposes. Trials of suggested methods were made at the station to secure venom from the marine toad, *Bufo marinus*. By gently squeezing the thyroid glands with the fingers, it was comparatively easy to

extract the venom. Apparently this operation did not cause the toad any great amount of discomfort and the gland recovered sufficiently so that in some instances the process could be repeated at the end of 3 weeks. After extraction the venom was dried in the air for a few days, approximately 1,000 toads yielding 130 grams of the dried venom. This was bottled, sealed, and shipped to H. Jensen of Johns Hopkins University.

The foregoing paragraphs outline the activities of H. L. Van Volkenberg, parasitologist of the station. During the year, investigations were conducted and information in regard to animal parasites was greatly augmented by the development of research projects by the Bureau of Animal Industry; E. W. Price, Eloise B. Cram, W. H. Wright, and L. A. Spindler of that Bureau, each was assigned for from 3 to 4 months in the island for the pursuit of special problems. Dr. Van Volkenberg collaborated with Dr. Price in making a survey of the liver fluke and of the internal parasites of the dog and cat, and with Dr. Wright in the studies of poultry parasites and anthelmintic experiments reported herein. More detailed accounts of the surveys and of the studies have been or will be published elsewhere.

REHABILITATION OF LAS MESAS LATERITIC SOILS

Puerto Rico has large areas of unproductive soils derived from serpentine.

Extensive areas of soils lie idle year after year because of their unproductive nature. Many of the infertile soils are underlain by masses of serpentine, in contrast to the majority of Puerto Rican soils which are derived from limestone and sedimentary material. These unproductive serpentine soils constitute a problem of pressing importance because of the dense population.

The Las Mesas property of the experiment station consists entirely of such unproductive soils derived from serpentine. They are soils of desirable physical character, easily plowed and cultivated, and easily drained, but unproductive. The area consists mostly of steep hillsides, but where the slopes decrease in steepness, or level off at the tops, such soils are more productive.

Technologists have advanced various diagnoses of the cause of this nonproductivity, such as the presence of toxic constituents in the soil and deficiencies of rare essential elements. The inference leading to the present studies, based on the topography, evidences of sheet erosion, and variation of productivity with the degree of slope, indicated simple but exaggerated deficiencies of such nutrients as nitrogen, phosphoric acid, and potash. The occurrence of fertile soils from serpentine of identical geological character under the conditions of sparse rainfall and little erosion in the Virgin Islands was an added observation leading to the inference that intense rainfall and resulting severe sheet erosion had depleted our Las Mesas soils of some of the most common but essential nutrients.

The following field experiment was therefore undertaken at Las Mesas, sweet corn being used as an indicator plant.

Phosphoric acid fertilizer was essential for sweet corn on Las Mesas.

In this fertilizer-constituent trial on unirrigated Las Mesas upland, friable red clay soil at an elevation of about 1,000 feet, nitrogen,

potash, and phosphoric acid were applied in various combinations at such rates as to give 80 pounds of each constituent per acre. There were six replicated plats of each treatment, and each plat was one-fortieth of an acre in area. The ground was moist before and after planting. All fertilizers were applied in the hills at time of planting. Cultivation was unnecessary because of the very sparse growth of weeds. The rates and kinds of fertilization, germination, and yields for the different treatments are shown in table 35.

TABLE 35.—*Yields in a replicated fertilizer-constituent trial with sweet corn USDA–34 in lateritic unproductive soils on the Las Mesas property of the experiment station* [1]

Symbol	Treatment	Application per acre						Germination	Days to tasseling	Yields per acre				Average weight per marketable ear
		Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Ammonium sulphate	Calcium superphosphate	Sulphate of potash			Marketable ears		Nubbins produced as proportion of total ears	Weight of ears	
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*		*No.*	*Kg*	*Pct.*	*Kg*	*G*
A	Nitrogen alone	80	0	0	383.03	0	0	59.5	87	0	0	-----	0	0.0
B	Nitrogen+phosphoric acid.	80	80	0	383.03	400	0	57.1	71	1,256	225.2	77.8	558.4	179.2
C	Nitrogen+potash	80	0	80	383.03	0	166.66	57.6	87	0	0	-----	0	0.0
D	No fertilizer	0	0	0	0	0	0	59.5	----	0	0	-----	0	0.0
E	Nitrogen+phosphoric acid+potash.	80	80	80	383.03	400	166.66	59.9	64	1,820	327.6	74.2	736.0	173.9

[1] Experiment by Davis, Lee, Watson, and Rodriguez. Planted Sept. 28, 1935, and harvested Jan. 9, 1936.

There were no significant differences in germination between the plats of the different treatments. The germination was low, but stands were complete, six seeds having been planted in each hill. The unfertilized plats practically ceased growth after the first month. In all plats lacking phosphoric acid growth was slow and corn production was nil.

Phosphoric acid increased number and weight of marketable ears.

As shown in table 35, phosphoric acid applied together with nitrogen resulted in an average production of 1,256 ears per acre. Unfertilized plats, as well as those treated with nitrogen alone, and plats treated with nitrogen plus potash, failed to produce a single marketable ear. Nitrogen plus phosphoric acid plus potash gave by far the best yields, confirming the results obtained with nitrogen plus phosphoric acid.

Phosphoric acid applied together with nitrogen also resulted in significant increases in total numbers of ears and total weights of sweet corn per acre. Plats so treated averaged 558.4 kilograms per acre in weight of both marketable ears and nubbins, whereas production was nil for unfertilized plats as well as for those treated with nitrogen or with nitrogen plus potash.

Yields were very low on even the most productive plats, apparently because the soil and the rock which weathered to form the soil were excessively low in plant nutrients.

Phosphoric acid apparently hastened tasseling of sweet corn.

The differences between plats treated with nitrogen plus phosphoric acid and those treated with nitrogen plus phosphoric acid plus potash when analyzed showed no statistical significance for total number of all ears, number of marketable ears, weight of marketable ears, number of nubbins, total number of ears, percent of number of nubbins to that of total number of ears, and weight per marketable ear. It should be stated, however, that all differences without exception were in favor of plats having the complete fertilizer. The greatest effect seemed to be on the number of marketable ears, while the least effect was upon total number of ears and total number of nubbins. It is felt that the lack of uniformity in the nature of the terrain and great soil heterogeneity between blocks containing all treatments contributed to reduce significance of the differences noted.

The plats treated with complete fertilizer were in tassel 1 week earlier than those treated with phosphoric acid and nitrogen; these latter were in tassel 16 days earlier than the plants in other treatments without phosphoric acid.

Growth measurements of sweet corn also showed response to phosphate.

Using the technique developed for sugarcane, growth measurements were undertaken in this experiment. They were begun 1 month after planting and taken at weekly intervals and are recorded in table 36. In figure 18, in which these measurements are graphed, each curve represents the average height increases of 72 plants, 12 marked plants being measured each week in each of the 6 replicated plats of each treatment. The growth increase of the unfertilized corn was very slight and barely exceeded 4 centimeters at its maximum. The corn treated with nitrogen grew nearly twice as rapidly as the unfertilized corn throughout the crop season. There was, however, very little response to potash, the growth curve for the corn treated with nitrogen plus potash being practically the same as that for the corn treated with nitrogen alone.

TABLE 36.—*Records of growth increments of sweet corn in Las Mesas fertilizer-constituent trial*

[Averages of 72 plants measured, 12 in each of the 6 replicated plats of each treatment]

Symbol	Fertilizer treatment per acre			Weekly average growth increments on respective dates									Total average height
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Nov. 4	Nov. 11	Nov. 18	Nov. 25	Dec. 2	Dec. 9	Dec. 16	Dec. 23	Dec. 30	
	Lb.	*Lb.*	*Lb.*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*	*Cm*
A	80	0	0	0.9	1.5	1.5	2.5	3.9	6.7	9.4	9.2	0	35.6
B	80	80	0	4.6	6.6	9.1	16.4	27.5	21.1	7.1	0	0	92.4
C	80	0	80	1.6	2.1	1.9	2.6	4.1	6.5	9.6	12.3	0	40.7
D	0	0	0	.7	1.1	1.0	1.4	2.2	2.6	3.9	4.6	0	17.5
E	80	80	80	5.7	9.7	14.7	24.0	24.7	16.1	6.6	0	0	101.5

The corn treated with nitrogen plus phosphoric acid grew from two to nine times as fast as that treated with nitrogen plus potash. The absence of growth response to potash was indicated also in the curves

showing growth increments of corn treated with nitrogen plus phosphoric acid as compared with the increments resulting from complete fertilizer, nitrogen plus phosphoric acid plus potash; in this comparison also there was no significant increased growth when potash was present.

The 2-week periods of maximum growth corresponded in each case very closely with the beginning of tasseling and was 1 week later for the nitrogen-phosphate plats than for complete fertilizer plats.

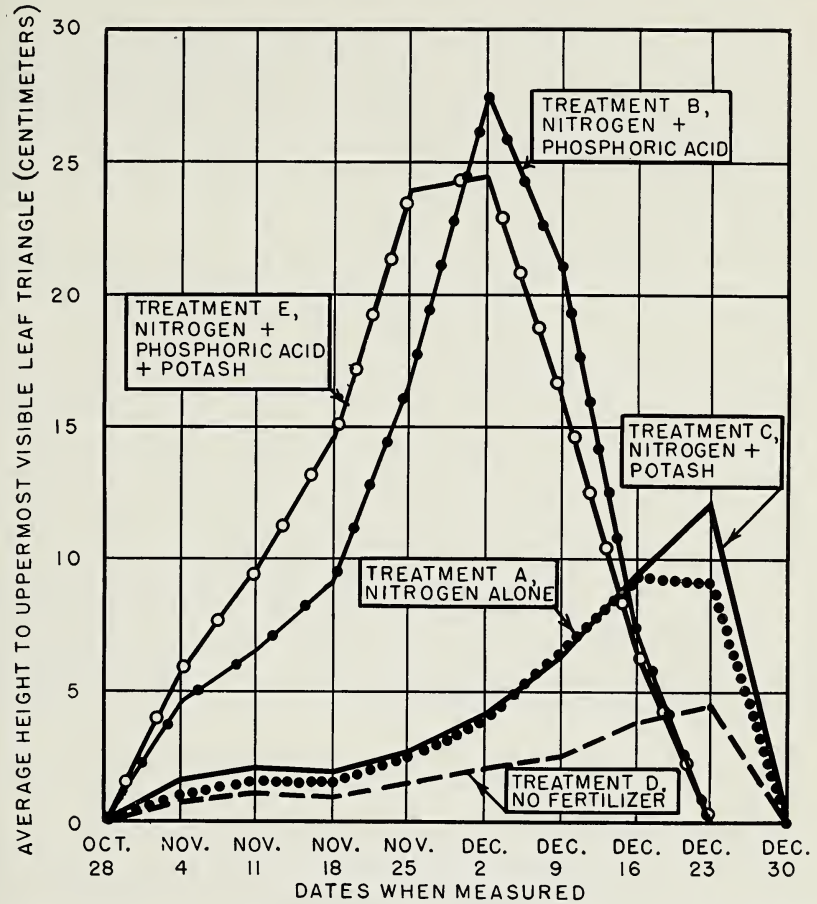

FIGURE 18.—Growth curves of USDA-34 sweet corn in Las Mesas fertilizer-constituent trial, September–December 1935. Each point in the curves represents the average growth increase per week of 72 corn plants, 12 plants being measured in each of the 6 replicated plats of each treatment.

The spread between maximum growth periods of plats which were treated with phosphate and those of plats which lacked phosphate was approximately 3 weeks, and this was likewise true for the tasseling periods.

Heavily eroded unproductive volcanic soils were made productive.

The evident conclusion is that these unproductive soils of serpentine derivation, which have suffered severely from sheet erosion, were made productive by satisfying deficiencies of the usual nutrients,

particularly phosphoric acid. Because of the favorable physical character of these soils and their fine capacity for quick drainage, apparently the rehabilitation of these soils can be made profitable.

Phosphoric acid applications were essential for production of corn forage at Las Mesas.

The forage weights of the corn in the different series of plats were also recorded and seem interesting. Table 37 gives the air-dry weights of stems and leaves combined for the six $\frac{1}{40}$-acre plats of each fertilizer treatment. It can be seen that the treatments containing phosphoric acid were much more productive than the unfertilized plats or those treated with nitrogen alone or those receiving nitrogen plus potash, and these large differences in production were statistically significant. The sweet corn forage production was two or three times as great in the nitrogen plus phosphoric acid plats or nitrogen plus phosphoric acid plus potash plats as in plats treated with nitrogen alone or in plats treated with nitrogen plus potash.

Nitrogen applications also gave increased yields on Las Mesas soils.

In plats to which phosphoric acid was not applied the addition of potash did not result in any increase in the weight of the tops as is shown in table 37.

TABLE 37.—*Air-dry weights of corn fodder in Las Mesas fertilizer-constituent trial* [1]

Symbol	Fertilizer treatment per acre			Average fodder per plat
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	
	Pounds	*Pounds*	*Pounds*	*Pounds*
A	80	0	0	21.23
B	80	80	0	53.77
C	80	0	80	19.65
D	0	0	0	9.63
E	80	80	80	65.35

[1] Planted Sept. 26, 1935, harvested Feb. 15, 1936.

The addition of nitrogen produced a growth of tops which was double that of unfertilized plats, and this difference was highly significant.

The forage weights were from 5 to 12 times as heavy in some of the unfertilized plats as in others, which indicates marked heterogeneity in soil. The differences in degree of slope presumably accounted for some of the extreme variability in productivity.

Potash added to phosphoric acid gave significantly increased growth.

The complete-fertilizer treatment resulted in significant increase in weight of stems and leaves over that of the nitrogen plus phosphoric acid treatment. There was a favorable response to the potash in the presence of phosphoric acid and nitrogen, whereas when phosphoric acid was omitted, the addition of potash to nitrogen was apparently not beneficial.

Las Mesas soils are not acidic.

The results of analyses made on soil in the fertilizer-constituent experiment are shown in table 38. Each analysis represents a composite sample obtained as follows: There were 5 treatments in this field-fertilizer test, each treatment being tested on 6 replicated plats.

Two soil samples were taken from each plat, and the 12 samples taken from the 6 plats of the same treatment were composited. The 5 composite samples were taken before the fertilizers were applied. The total area of plats from which samples were taken was three-fourths of an acre.

TABLE 38.—*Results of analyses of soil samples taken from series of plats in a fertilizer-constituent experiment on corn at the Las Mesas property of the experiment station* [1]

[The 5 analyses are from composited soil samples, each composite representing a series of 12 samples, 2 samples being taken from each of 6 plats devoted to a similar fertilizer treatment. Percentages show total content and are on dry-weight basis]

Sample	Acidity	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Lime (CaO)	Magnesia (MgO)	Silica (SiO_2)	Iron oxide (Fe_2O_3)	Aluminum titanium oxides (Al_2O_3 TiO_2)	Manganese oxide (MnO)	Chromium oxide (Cr_2O_3)
	pH	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	7.15	0.352	0.015	0.046	0.43	3.62	18.78	42.34	13.83	0.10	1.25
B	6.95	.331	.012	.084	.36	2.32	20.26	44.48	15.04	.22	1.25
C	6.91	.371	.012	.066	1.20	4.29	22.18	38.83	13.65	.07	1.16
D	7.25	.363	.011	.077	.95	3.54	21.16	40.65	14.16	.22	1.26
E	7.25	.343	.011	.042	.84	4.39	22.16	38.61	15.27	.20	1.23

[1] Analyses by Carrero.

The prevailing opinion has been that Las Mesas soils are acidic; the results in table 38 show that the soils are as nearly neutral as one is apt to find in any considerable area of volcanic soils receiving similar amounts of precipitation. The prevalent conception is that neutral soils are close to optimum for the production of sugarcane and possibly other grass crops.

These unproductive soils showed favorable nitrogen content.

Table 38 also shows that these soils had a favorable nitrogen content. Apparently in spite of the severe erosion on these steep hillsides under conditions of intense rainfall, the nitrogen has persisted and has not been leached or eroded away.

Phosphoric acid is the nutrient which is critically deficient.

The analyses show that phosphoric acid is so deficient as to become a limiting factor in production. This may be stated with even more assurance in view of the very significant responses from phosphoric acid fertilizers obtained in the field tests recorded in the preceding paragraphs. It will be recalled that the plats which had received phosphoric acid gave a much larger yield than any of the other series of plats, producing a crop which was almost commercially successful. In view of the results of the field tests, corroborated by the results of analyses in the foregoing tabulation, the deficiency in phosphoric acid seems to have been the major cause of the unproductive nature of Las Mesas soils.

The potash content of these soils was also low, but not so seriously low as in the case of the phosphoric acid.

Lime-magnesia ratio was very low.

In experience with sugarcane soils the lime-magnesia ratio varies from 2:1, 3:1, or even 4:1. In table 38 it can be seen that the lime content was extremely low, and the magnesia content was relatively high. The lime-magnesia ratio in some of these analyses was as low

as 1:8 and in every case the magnesia content was three to four times greater than the lime content.

Silica content was low; iron very high.

The analyses showed that the silica content of these soils was low. The iron oxide content was remarkably high. These two features make these Las Mesas soils highly distinctive.

Aluminum excess apparently was not cause of unproductive nature of soil.

The analyses in table 38 also indicate that the aluminum content is not unusually high. Aluminum injury in corn and sugarcane is rather distinctive in appearance, and no symptoms in the corn grown in the Las Mesas experiment would indicate any aluminum toxicity in these soils. Moreover, the pH value of these soils was not so low that aluminum injury would be expected.

The manganese content of the soils was apparently not abnormal and was in concentrations not sufficient to cause any manganese toxicity or low enough at the present soil reaction to cause any manganese deficiency.

An outstanding feature of Las Mesas soils was the chromium content, which was considerably higher than in most agricultural soils. Some of the qualitative reactions indicated that the chromium to a considerable extent was in the form of insoluble iron chromite; the significance of this would be to indicate that the chromium in such case would be unavailable to plants and chromium toxicity would not be expected.

Las Mesas soils showed high clay content.

In table 39 data resulting from the physical analyses of soils in the fertilizer-constituent experiment on corn at Las Mesas are presented.

TABLE 39.—*Physical analyses of lateritic soils in a fertilizer-constituent experiment on corn at the Las Mesas property of the experiment station* [1]

Sample from treatment [2]	Gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Total sand and gravel	Clay
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
A	6.00	4.22	4.07	6.65	6.10	27.04	72.96
B	5.17	6.26	4.93	5.90	5.54	27.80	72.20
C	5.09	5.98	4.52	6.31	6.22	28.12	71.88
D	5.56	5.74	3.57	5.63	6.03	26.53	73.47
E	5.03	5.91	3.36	6.60	5.91	26.81	73.19

[1] Analyses by Rodriguez.

[2] A composite sample was made by mixing equal parts of soils from each of the 6 replicated plats receiving similar treatment and the data presented here are analyses of such composite samples.

Due to the high concentration of colloidal clay, this soil separate was obtained by making use of the Sudan method, which varies from the beaker method used for the other soil separates in that 2-percent and 0.05-percent sodium carbonate solutions are used instead of solutions of ammonium hydroxide and distilled water.

The gravel and sand from these soils are the products of rock disintegration from the upper slopes which apparently have been washed down during periods of heavy rain. The high clay content is noteworthy in these soils, as indicated in table 39, and varied between 71.88 and 73.47 percent. The average clay content for the whole area, about three-fourths of an acre, was 72.74 percent.

CHEMISTRY INVESTIGATIONS

Routine analyses of a service nature were made.

The chemistry division is called upon to cooperate almost constantly with other divisions of the experiment station and with other agencies of the departments of the Federal and the Insular Governments. Many of these services are contributed with little or no recognition, but the records of analyses accumulating over a number of years build themselves into classified files of information from which it is expected many interesting conclusions can ultimately be obtained. Many inquiries have been received requesting the chemical composition of various tropical fruits, plants, and soils, some of which can frequently be answered from information in the records.

During the year a great number of samples of limestone rock were submitted by the Puerto Rico Reconstruction Administration for analysis in studies to determine their suitability as a raw material to enter into cement manufacture. Samples of well water have been submitted by sugar planters to determine their salt content and the nature of the salts and the adaptability of such waters for irrigation. Analyses have also been made of a great number of soil samples not only for the solution of the problems of the personnel of the station, but also for sugar planters and other agricultural enterprises.

Cattle feeds of high protein content exist in the Tropics.

Each year the island imports from the continental United States cattle feeds, usually concentrates, the general belief being that foodstuffs of protein and high carbohydrate content are not available here for the feeding of farm animals. In the fiscal year 1933–34 the importations of concentrates totaled to a value of $599,822 and in the year 1934–35 the importations were valued at $594,310.

It was observed that dairy animals of the experiment station, purebred, registered Guernseys, ate avidly of the shade- and moisture-loving weed known locally as "cohitre", *Commelina elegans*. The cattle also fed avidly on the leaves of the common leguminous tree known as "bucare", *Erythrina poeppigiana*, and "bucare enano", *E. berteroana*. Neighboring farmers reported that their dairy animals also eagerly consumed these plants whenever they were available. *C. elegans* occurs extensively in the districts of abundant rainfall as a weed and ground cover in sugarcane fields which have closed in; it is also found abundantly in shaded parts of coffee plantations where it is of value in checking soil erosion.

Samples of the foliage of the *Commelina* and two species of *Erythrina* were analyzed, and the results obtained are shown in table 40. All

TABLE 40.—*Results of analyses of leaves of Erythrina poeppigiana and E. berteroana, and leaves and stems of Commelina elegans as foodstuffs for farm animals* [1]

Basis and plant species	Moisture	Dry matter	Ether extract	Nitrogen	Crude protein	Ash	Reducing sugars	Sucrose	Total carbohydrates	Crude fiber
Fresh green material:	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Erythrina berteroana	79.93	20.07	1.04	0.86	5.37	1.70	[2]	0.39	2.24	3.69
Erythrina poeppigiana	72.50	27.50	1.44	1.33	8.30	2.22	[2]	[2]	2.80	5.63
Commelina elegans	88.90	11.10	.48	.39	2.46	1.84	0.48	.01	1.60	1.22
Dry basis:										
Erythrina berteroana	-------	-------	5.17	4.28	26.75	8.49	[2]	1.97	11.16	18.39
Erythrina poeppigiana	-------	-------	5.23	4.83	30.19	8.07	[2]	[2]	10.17	20.49
Commelina elegans	-------	-------	4.30	3.55	22.19	16.57	4.36	.11	14.43	10.99

[1] Analyses by Carrero.

[2] Trace.

samples were taken from mature plants but with the leaves in a fresh green condition.

It can be seen that on a moisture-free basis the protein content of both *Erythrina* species was very high, and the protein content of cohitre, although less, was notable. The percentage of carbohydrates was comparatively low in all species.

The crude protein content of alfalfa hay, according to standard analyses, is approximately 14.7 percent. By comparing this figure with the figures in table 40, it can be seen that on a dry basis not only the *Erythrina* species, but also the *Commelina* compared very favorably with dried alfalfa as regards protein content. However, the high moisture content of the *Commelina* makes comparison with alfalfa much less favorable when the proteins are measured in fresh green material. The protein content of the bucare species even in the fresh green material is considerably higher than the usual figures for alfalfa, namely, 2.1 to 3.5 percent.

As regards carbohydrates, however, alfalfa, even the green roughage, has a content of from 7.5 to 13.5 percent, which is much higher than the carbohydrate content of either the *Erythrina* species or *Commelina*.

The station has supplemented the carbohydrate content of its green roughage for dairy feeding with sugarcane put through a silage cutter, and in the absence of sugarcane has supplemented the ration with molasses. Sugarcane, with its juices containing from 10 to 16 percent of sucrose, is in itself a source of concentrated carbohydrates and after passage through the silage cutter is eaten avidly by dairy animals.

Seeds of royal palm are high in fat content.

Since hogs feed avidly on seeds of the royal palm, *Roystonea* (*Oreodoxa*) *regia*, for years it has been the practice of farmers of the island to feed such seeds to their hogs. The royal palm bears large clusters of hundreds of seeds, each seed approximately the size of a small olive, on well-matured trees 70 to 100 pounds of such seeds being borne annually.

During the year a trial was made of feeding these seeds to the dairy herd of the station; approximately 100 pounds of these seeds were harvested each day and run through the silage cutter with the sugarcane or other green fodder to be given to the dairy animals in the evening. It was found that calves ate and digested the seeds readily, but cows would not eat the seeds unless well mixed with other attractive feedstuffs, and there were evidences that the seeds were not completely digested. Because of the possibility of using this product, at present largely wasted, as a source of fats for dairy animals, analyses were made which are listed in table 41.

TABLE 41.—*Results of analyses for fat content of seeds of the royal palm, Roystonea (Oreodoxa) regia* [1]

Condition of seed [2]	Fresh-weight basis						Crude fat on dry basis	
	Moisture		Dry matter		Crude fat			
	Percent	Average percent	Percent	Average percent	Percent	Average percent	Percent	Average percent
Immature, easily crushed	69.93 69.90	69.92	30.07 30.10	30.08	2.06 2.09	2.08	6.84 6.94	6.89
Full-sized, hard but still immature	67.20 67.15	67.18	32.80 32.85	32.82	2.71 2.74	2.72	8.27 8.36	8.32
Mature, yellow, hard nuts	56.90 56.85	56.88	43.10 43.15	43.12	8.32 8.35	8.33	19.30 19.36	19.33

[1] Analyses by Carrero. [2] Two samples were analyzed for each of 3 degrees of maturity tested.

Neither facilities nor personnel have been available for accurate feeding tests of feedstuffs that are sources of proteins and fats. However, it is possible to say that for reasons of economy the dairy herd of the station has been maintained almost entirely on these island products throughout the year; weights have been taken monthly, and there have been no losses in weight in the animals, but on the contrary there has been a slight increase in weight during the period. The milk production has been less, but the savings in feed costs have made the dairy more profitable in spite of the lessened production. Two registered Guernsey heifer calves and one bull calf have been reared during the last 18 months exclusively on these island feeds with every evidence of success.

The foregoing analyses cannot be taken as a substitute for feeding tests but form a substantial basis for the utilization of cheaper local feeds for dairy animals. The conception of the experimental personnel who have followed this work and are familiar with the dairy situation of the island is that feeding of concentrates should not be lessened and even could be increased; but that feeding of these local sources of proteins and fats can profitably supplement the present concentrate rations.

Analysis of fruit of mango varieties.

In connection with some work upon mango varieties at the station during the year by Hamilton P. Traub of the Bureau of Plant Industry, analyses were made of the juices and pulp of some representative mango varieties grown in the station collection. The results of the analyses are listed in table 42.

TABLE 42.—*Analyses of juice and pulp of fruits of mango varieties in the experiment station collection* [1]

Variety	Moisture content	Juice					Pulp		
		Brix reading	pH	Tenth normal NaOH per 100 cc	Invert sugar	Sucrose	Invert sugar	Sucrose	Nitrogen
	Percent	*Degree*		*Cubic centimeters*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fajri Long	82.5	17.2	4.50	31	3.65	12.38	3.25	10.86	0.094
Sufaida	83.5	15.1	5.13	20	3.27	11.52	3.14	10.71	.089
Amini	84.9	16.9	3.87	76	2.58	12.67	2.24	11.26	.080
Itamaraca	83.7	18.8	4.37	34	3.26	14.04	2.96	12.80	.082
Mullgoa	77.2	17.8	3.97	83	2.04	13.64	1.61	12.87	.094
Divine		17.6	4.26	59	3.22	7.53	2.89	6.51	.090
Cambodiana	82.0	16.4	4.26	80	2.89	11.26	2.63	10.59	.092
Sandersha		11.3	3.45	107	3.19	7.10	2.30	6.92	.082
Totafari		15.9	3.74	96	3.40	10.26	3.16	9.12	.077

[1] Analyses by Carrero.

It is evident from table 42 that the basic determinations of sugar and nitrogen content cannot be substituted for the more indefinite factor of taste upon which sales and prices are dependent. The analyses are being studied in relation to comparative susceptibility of these varieties to the fruitfly but additional data are necessary before conclusions can be presented. The determinations of pH values and total titratable acids have been of considerable value in preliminary experiments in canning mangoes.

J. O. Carrero, assistant chemist, has not only carried on the foregoing investigations but has also cooperated extensively with other divisions of the experiment station in chemical studies fundamental to many station activities.

BIOMETRIC SERVICE AND RESEARCH

Biometric control of agronomic experiments was developed during the year.

Field experiments, and in most cases laboratory tests as well, during the past year were subjected to a regular routine of preliminary planning. Wherever possible, in the design and lay-out of such experiments advantage was taken of all the known statistical methods that were applicable. The proposed site of each experiment was selected and experimental technique was devised to reduce variability within types of treatment. The results of each experiment were then analyzed statistically to determine the significance of differences noted. Such procedures provided an integrated method of control of experimental methods.

Improved plat technique and statistical analysis of results.

In the past year the development of a field experiment has included conference with the technologists concerned and the mutual drawing up of plans for the plat lay-out; these procedures have increased manyfold the amount of information obtained from a given expenditure of research funds, as well as permitting statistical analyses which in turn enables the accuracy of the information secured to be determined. Statistical analyses also helped to improve the methods of experimentation and to determine whether the data secured were within the desired limits of accuracy, so that, if any type of experiment was found to be unprofitable, further expense of continuing it could be avoided.

During the year the division of biometry provided other divisions of this station, as well as related agencies of the Department of Agriculture in Mayaguez, with consultation service in the planning of experiments in accordance with established biometric practice. Such service involved suggestions as to the size and shape of plats, number of replications necessary, the validity of conclusions, and methods of graphic and tabular presentation of results. This division was also active in cooperating with experiment stations privately owned by sugar centrals in placing their experimental agronomy on a biometric basis. The value of these services has already been reflected in the reduction of experimental costs and the increased accuracy of results.

Studies have been made of the characteristics of variability and behavior of plants on which considerable amounts of work are being done. Such studies in some cases made possible a reduction of the number of replications with consequent savings in costs of experimentation. Soil plat maps were made to detect irregular-yielding areas which would be expected to give abnormal results. The results of experiments were reviewed to determine factors responsible for variations noted in plats receiving similar treatment, and these factors were then considered from the viewpoint of plant physiology as well as of biometry. The division of biometry is considered in part as a service division for making its background of experimental technique and statistical analyses available to the activities of other divisions of the experiment station.

The activities in biometry have been carried on by Alfred N. Watson.

PLANT INTRODUCTIONS AND DISTRIBUTIONS

Almost 500 plant species were introduced during the year.

Propagating material of 457 species of plants was received during the year. These introductions consisted of 210 ornamentals, 10 palm species, 6 forest-tree species, 8 oil-producing species, 24 fruit and nut trees, 7 lawngrass species, 5 bamboos, 10 root-crop species, 17 quinine-yielding species, and 160 insecticidal species.

The associate horticulturist made a 5-day trip to St. Croix and St. Thomas, Virgin Islands, during August 1935 to obtain cuttings of the insecticidal species *Derris elliptica* for planting at this station. Two hundred and ninety-six cuttings of this species were obtained from plants grown by the Virgin Islands Experiment Station from seed that had been imported from Java in 1929. The opportunity was also taken to obtain propagating material of other species of economic and ornamental plants, which are included in the foregoing summation.

Quinine plants were introduced.

In 1933 some *Cinchona* plants were sent to the Forestry Service of the Insular Government by the Bureau of Plant Industry; these were set out in the Maricao Forest. During the first year after planting these plants developed very irregularly, but later, after becoming established, those plants which survived have grown satisfactorily. During 1935 the Forestry Service turned these plantings over to the experiment station for administration.

In early June 1935 an extensive collection of additional *Cinchona* plants was sent to the station by the Bureau of Plant Industry; some of these plants were combined with the 1933 planting at the Maricao Insular Forest, others were planted on the Las Mesas property of the station, and still others at Doña Juana in the Toro Negro unit of the Caribbean National Forest. Some significance attaches to the elevation of these plantings, the Toro Negro planting being at an elevation of about 3,000 feet, the Maricao planting 2,000 feet, and the Las Mesas planting about 1,000 feet. The soil at Las Mesas and Maricao is similar in type, being a lateritic clay of serpentine origin; that at Doña Juana is of a lighter nature and is derived from shales.

The quinine plants introduced in 1935 consisted of 17 species or hybrids of species; representatives of all these species were planted at Doña Juana on the theory that they would thrive in that high elevation. Only four species were planted at both Las Mesas and Maricao, namely, *Cinchona ledgeriana* × *succirubra*, P. I. 104222; *C. officinalis*, P. I. 104223; *C. succirubra*, P. I. 100118; and *C.* sp., possibly *ledgeriana*, P. I. 104269. Thus the plantings at all three elevations include these four species. Table 43 lists the number of plants of each species and hybrid introduced and the locations where planted.

The results at Doña Juana have not been encouraging; more than 50 percent of the plants died without making any growth. Five plants, set out near one rotted tree stump, grew much better than those in other parts of the plantation. It was suspected that the organic matter derived from this rotted tree supplied some nutrients that were not sufficiently abundant in other parts of the planting, and consequently an application of mixed fertilizer of the formula 12–8–5

TABLE 43.—*Number and location of plants of introduced Cinchona species and hybrids, planted in Puerto Rico in May and June 1935*

Species	P. I. no.	Location			
		Doña Juana	Las Mesas	Maricao	Total
		Number	*Number*	*Number*	*Number*
C. calisaya	101064	67			67
Do	101240	10			10
C. ledgeriana	104269	396	5	5	406
C. ledgeriana × *officinalis*	100115	6			6
Do	104221	115			115
C. ledgeriana × *succirubra*	100116	9			9
Do	104222	127	2	2	131
C. officinalis	100117	2			2
Do	100987	2			2
Do	104223	191	5	5	201
C. succirubra	100118	10	2	2	14
Do	100988	7			7
Do	101661	3			3
C. species	100824	1			1
Do	100825	1			1
Do	103021	21			21
C. species de "Chajel"	103022	7			7
Total		975	14	14	1,003

was applied uniformly near each plant of the entire plantation; apparently no response was obtained from this treatment. The rainfall at Doña Juana was much below normal during most of the year and, therefore, the fertilizer may not have been available to the plants; however, at Maricao the rainfall was also below normal, but notwithstanding this fact the plants there have grown well.

The plantings at both Maricao and Las Mesas contain specimens of each of four species in some degree of vigor; apparently the four species represented in each of these plantings have been established in the island. Because of the comparative success of the quinine plants at Maricao and Las Mesas the plants at Doña Juana may be transferred to these two sites.

Collection of mango varieties from famous mango regions.

It has been stated by horticulturists of repute that this station has what is perhaps the world's largest collection of mango varieties. The station's mature mango groves include outstanding varieties from southern Asia, the Malay Archipelago, the West Indies, South America, and Florida. The groves include 600 trees, 424 of which represent 59 definite varieties, and 176 are seedlings of 32 of these varieties. Of the 59 varieties, the 43 listed below fruited during 1935–36.

Alphonse.	Climoise.	Fernandez.	Mullgoa.
Ameeri.	Concord.	Giraffe Seedling.	Mulgoba.
Amini.	Costa Rican.	Gola.	Paheri.
Bombay Green.	Cuban.	Haden.	Peter's No. 1.
Bombay Yellow.	Davy's Favorite.	Hafu Alphonse.	Reine Amelie.
Borsha.	Divine.	Itamaraca.	Sandersha.
Brindabani.	Douglas Bennett's Alphonse.	Jamshedi.	Sans Pareille.
Bulbulchasm.		Kachmahua.	Savoy.
Cambodiana.	Enuria.	Kistapal.	Singapur.
Carabao.	Faizan.	Madras.	Sufaida.
Chempadan.	Fajri Long.	Martinique.	Totafari.

The seedling grove of 176 trees was obtained from seed from the other groves of standard varieties and offers good possibilities for producing worth-while varieties. The fruits that produced these seed-

lings did not result from controlled pollination, but from naturally occurring pollination in the groves in which the different varieties were growing interspersed and contiguous to each other.

Due to the rose-pink coloration of its skin, one seedling of the variety Bulbulchasm was judged to be superior to its female parent, and in other respects it was at least equal to its parent. In flavor and texture none of the other seedlings which fruited during the past season were found to be superior to their female parents.

Grasses for lawn trials.

The station's lawns have been composed of the fine-leaved, low-growing Java grass *Polytrias amaura*. This grass at first produced beautiful lawns under Mayaguez conditions; however, in the last year it has been subject to much damage by diseases and insects which cause dead, unsightly brown areas. The local chinch bug, *Blissus leucopterus* var. *insularis* Barber, is apparently the worst insect pest.

Due to such difficulties in maintaining good lawns of this Java grass, other lawn grasses have been assembled for comparative trials under Mayaguez conditions. Seven such grasses were received from the Bureau of Plant Industry during the year and are being propagated for more extensive plantings. They are Bahia grass, *Paspalum notatum;* centipede grass, *Eremochloa ophiuroides;* velvet grass, *Zoysia tenuifolia;* Manila grass, *Zoysia matrella;* Korean lawngrass, *Zoysia japonica;* carpet grass, *Axonopus compressus;* and St. Augustine grass, *Stenotaphrum secundatum*. Of these, the last two already occur in the island. In the time these grasses have been under observation, the centipede grass and Manila grass have made the most desirable development.

The grasses most commonly used for lawns in the island are St. Augustine grass; carpet grass; Bermuda grass, *Cynodon dactylon*; and grama, *Paspalum conjugatum*. The fine-leaved Bermuda grass is most used in drier parts of the island. In the moist regions it grows well only in sandy, well drained areas. The other indigenous grass, *P. conjugatum*, is often found mixed with carpet grass in lawns. These two grasses and St. Augustine grass are used chiefly in the regions of heavy rainfall. The carpet grass and *P. conjugatum* form dense dark-green lawns, while the St. Augustine grass forms dense light-green lawns. All three of these are broad-leaved grasses, and therefore form lawns of a coarse appearance.

Two indigenous leguminous plants show promise of usefulness for lawns; the small-leaved *Meibomia triflora* produces a dark-green dense turf, while the unifoliate *Alysicarpus vaginalis* covers the ground but has the objectionable character of sending up flowering branches which give the turf an uneven appearance.

An acre of the perfume-producing tree, ilang-ilang, was planted.

Ilang-ilang, *Canangium odoratum*, is a tree indigenous to southeastern Asia and the East Indies, the flowers of which yield a fragrant, volatile oil which enters into the manufacture of some of the best perfumes. Ilang-ilang trees grow well in western Puerto Rico and are adapted to hillside cultivation where also, in many cases, they would receive some degree of protection from hurricane winds.

An experimental planting of 190 ilang-ilang trees, covering slightly more than an acre, was made at the station during the year for the purposes of obtaining costs of production, and utilizing the yields for experimental distillations.

In order to utilize to the fullest extent the investment in the planting a replicated experiment is also going on testing nitrogen fertilizer against no nitrogen in the production of ilang-ilang. The orchard, planted on a hillside with a slope of approximately 45 percent, has been protected against soil erosion by lateral contour canals which prevent the accumulation of large volumes of water, and lessen its velocity, during the heavy rains of western Puerto Rico.

To utilize the land while the trees are growing a planting of the food-producing, leguminous pigeonpea *Cajanus indicus* was made in contoured rows, which have also aided in checking soil erosion.

34,641 plants and cuttings were distributed during the year.

In furtherance of the policy of Gov. Blanton Winship to make Puerto Rico attractive to tourists, the station contributed many ornamental plants to other governmental institutions, as well as to agriculturists and other interested individuals. Public institutions such as the Weather Bureau, Army posts, schools, and churches requested many of the ornamental plants which have been distributed. One landscaping project that is expected to be of outstanding value consists of a planting of crimson Buginvillaea at Fort El Morro overlooking the entrance to San Juan harbor. More than 500 plants were contributed to this project which, when well developed, should result in a mass of crimson giving a colorful first impression of Puerto Rico to visitors entering the harbor. Table 44 summarizes the plant distributions, both economic and ornamental, made during the fiscal year 1936.

Claud L. Horn, associate horticulturist, was in charge of plant introductions and distributions during the year.

TABLE 44.—*Distribution of economic and ornamental plants during 1935–36, listed by classes and months*

PLANTS

Plant	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
Sugarcane cuttings									4,016				4,016
Bamboo, industrial				6	8	24	5	2		2	12	332	391
Avocado varieties				50	2			3	2		2	6	65
Citrus varieties				15			400			4	30		449
Mango varieties	14	24		32	8	10	2	11	15		524	45	685
Hibiscus varieties	339	744	466	1,116	1,314	837	824	597	723	454	2,697	2,390	12,501
Palms	10	8	92	100	154	42	7	31	27	39	237	1,574	2,321
Violet tree [1]			5	2	11	1		1	1	2	1		24
Buginvillaea varieties	43	25	175	100	249	16	51	103	168	197	318	95	1,540
Waterlilies		4	100	4	4		2		8	18	11	4	155
Miscellaneous economic plants	13	76	129	711	5		273	43	218	6	259	36	1,769
Miscellaneous ornamental plants	58	312	421	1,087	668	237	821	438	211	776	940	1,575	7,544
Miscellaneous fruit plants	16	76	250	107	164	39	511	88	22	17	17	58	1,365
Ornamental vines	79	422		118	75	46	496	20	12	37	134	143	1,582
Pride of India [2]	28	5	1										34
Ilang-ilang	6	8	36										50
Wax flowers [3]		6		18	10		1	5		12	70	12	134
Cannon-ball tree			16										16
Totals	606	1,710	1,691	3,466	2,672	1,252	3,393	1,342	5,423	1,564	5,252	6,270	34,641

SEEDS AND SOD

Tropical sweet corn seed ..... pounds									32				32
Lawngrass sod ..... square feet			150	150									300
Mahogany seed ..... pounds										30½			30½

[1] *Phlebotaenia corellii.* [2] *Lagerstroemia speciosa.* [3] *Phacomeria speciosa.*

SERVICES TO ANIMAL INDUSTRY

Many diagnoses of sick animals are requested.

The services of Dr. Van Volkenberg, the parasitologist, are frequently requested for aid in the diagnoses and advice as to the control of diseases of animals. Fecal examinations for parasites, blood tests for anthrax, anaplasmosis, piroplasmosis, and infectious abortion, inspection of carcasses to determine the fitness of meat for food purposes, and autopsies to ascertain the cause of death have been among the most frequent services rendered the livestock industry.

The station receives many requests by mail for advice concerning the diseases and also the feeding and management of domestic animals. As such information is often available in bulletins published by the Department, the station maintains a stock of Farmers' Bulletins for free distribution in answering these requests.

The station has continued to maintain two purebred registered Guernsey bulls and during the year 78 cows were served by these animals.

During the year 2,244 dairy animals were dipped in the deticking vat of the station.

WORK OF THE CORRELATING COMMITTEE

The correlating committee, which was organized in 1934 to prevent duplication of the work of Government agricultural institutions in the island and advance the work of each by cooperation, continued to function successfully. This committee consists of the dean of the College of Agriculture and Mechanic Arts, the director of the Experiment Station of the University of Puerto Rico, the director of agricultural extension of the University of Puerto Rico, the Commissioner of Agriculture and Commerce, and the director of the Puerto Rico Experiment Station of the United States Department of Agriculture.

A number of meetings were held which have continued to insure that there will be no duplication of investment of Government money, either Federal or Insular, in identical lines of research. Each agricultural agency continued to contribute to the advancement of the projects of the others as a result of these meetings. Appreciation is expressed for the sincere and effective cooperation of the members of the committee.

COOPERATIVE PROJECTS

Cooperation with the Federal Emergency Relief Administration of Puerto Rico.

A number of cooperative projects were undertaken with the Federal Emergency Relief Administration of Puerto Rico. The experiment station loaned the use of 30 acres of land for the production of subsistence crops, providing not only employment but considerable supplies for the commissary of the Emergency Relief Administration. The crops planted consisted of bananas and yams.

The Emergency Relief Administration furnished a number of men for the propagation of recently introduced bamboo varieties and shop men for studies in the utilization of bamboo. During the year a number of men were furnished for the planting of seeds of newly introduced mango varieties. A squad of men was also provided for top-working undesirable mango trees with budwood of some of the

new fiberless mango varieties. Additional men were provided for the construction of bench terraces for the utilization of waste land and to check soil erosion.

The F. E. R. A. constructed a reinforced-concrete building to house the low-temperature and high-temperature equipment subsequently made available by the Bureau of Entomology and Plant Quarantine for their studies on the sterilization of Puerto Rican fruits to kill the West Indian fruitfly.

The fine cooperation is acknowledged from the F. E. R. A. which it is believed was mutually advantageous.

Cooperation with the College of Agriculture and Mechanic Arts.

The director of the experiment station was appointed to the faculty of the College of Agriculture and Mechanic Arts, the intention being to increase the feeling of cooperation between the two agencies; acting in that capacity, several lectures have been given at the college during the year. The station continues to make available several acres of land for the dairy of the college. The faculty of the college have from time to time cordially contributed their technical background for the advancement of the projects of the station.

Commissioner of Agriculture and Commerce contributed to advancement of station projects.

The almost constant assistance of the Insular Commissioner of Agriculture and Commerce in the advancement of the interests of the experiment station is gratefully acknowledged. The Department of Agriculture and Commerce arranged for an exhibit of the products of the bamboo-utilization shop in New York and Philadelphia. Frequent use has also been made of the library of the Department of Agriculture and Commerce. Contributions have been made by members of the station staff to the Revista de Agricultura, the official organ of the Department of Agriculture and Commerce. The personnel of the Department of Agriculture and Commerce and the personnel of the experiment station have worked closely on a number of projects in which they were mutually interested and to the considerable advantage of such projects.

Insular and Federal experiment stations act as a unit.

Due to the keen desire for cooperation of the director of the Insular experiment station, the Insular and Federal experiment stations are acting almost as a single unit. Advices are exchanged concerning new projects, the advancement of long-continued projects, and personnel available for such projects. Plant material has been exchanged, and equipment and library facilities are being utilized by both entities. The Insular experiment station continues to maintain its coffee specialist at this station, where a number of cooperative coffee projects are under way. There has been no lost investment of Government funds, either Federal or Insular, from duplication or omission of work by these two institutions.

Agreement has been signed with the Puerto Rico Reconstruction Administration.

Toward the completion of the year a cooperative agreement was signed with the Puerto Rico Reconstruction Administration by which the experiment station will furnish land for a workers' reconstruction camp to be organized and financed by the Administration. This

workers' camp will be devoted to research, and demonstration work in the prevention of soil erosion. The camp is to consist of 200 men who will spend a number of hours each day on soil-conservation projects, the remainder of the day being utilized for their education, not only in agricultural sciences, but in citizenship, hygiene, nutrition, and such subjects. At the conclusion of the fiscal year, work had already gotten under way on the construction of the barracks for this camp.

Mutually advantageous cooperation with the municipality of Mayaguez.

The mayor and council of the city of Mayaguez have continued their cordial cooperation throughout the year. An ornamental street light at the entrance of the station was erected by the city which, beautified with tropical plantings, has enhanced the beauty of the entrance to both the city of Mayaguez and the experiment station. Road repairs have been made by the city. Ornamental plants have been made available by the experiment station for park plantings.

The station grounds are continuously open for visitors from the city, and on Sundays and holidays there are sometimes 50 or more visitors a day to the tropical gardens and lawns of the station. Between 2,000 and 3,000 visitors have called at or visited the gardens of the experiment station during the year.

ADDITIONAL LAND TRANSFERRED TO THE EXPERIMENT STATION

Legislature of Puerto Rico transferred 190 acres of land to the station.

Since 1910 the experiment station has had the administration of 190 acres of land 3 kilometers to the east of the city of Mayaguez. The area is at an elevation of 1,000 feet and consists of soils of volcanic origin in contrast to the sedimentary soils at close to sea level in the lowland property of the station. This upland area therefore has been advantageous in the study of plants newly introduced to Puerto Rico, affording an environment decidedly different from that at the lowland fields of the station. The water supply of the station is obtained from a reservoir fed by springs on this upland property. The authority to administer this land was not clear, having been merely contained in a letter in 1910 from the Commissioner of the Interior for Puerto Rico, to the then director of the station.

During the year the Legislature of Puerto Rico passed a bill transferring this land to the Puerto Rico Experiment Station of the United States Department of Agriculture, making title and authority clear as to the administration of the land. The bill, introduced and sponsored by the Senators and Representatives from Mayaguez, received only ecomiums and no opposition.

The confidence of the Senators and Representatives who constituted the Legislature of Puerto Rico in transferring this acreage of the constantly diminishing public lands of the Territory to the administration of the experiment station is sincerely appreciated. Results of experiments have already been obtained which transform this area, previously considered as sterile and waste land, into productive land profitable to cultivate in vegetable and other crops of high value per acre, thus justifying to some extent the confidence reposed in the station by the legislature.

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IMPROVEMENTS IN PROPERTY

Improvements in buildings.

As mentioned under Coffee Investigations, a new office, laboratory, and processing building has been developed by modifications made in an existing concrete, tile-roofed storage building. By the use of wallboard, carpentry, and paint 1,275 square feet of floor space have been obtained for coffee research work. The building is most advantageously situated in relation to the coffee orchards and to the equipment for depulping and drying the coffee. Running water and electric lights were also installed.

One of the original buildings on the property when it was transferred to the experiment station in 1901 was an old sugar mill with thick brick walls and tile roof. This has been used in past years as a garage and storehouse. During the year partitions and windows were constructed, wall benches installed and, with electric wiring and compressed air, an efficient wood-working shop comprising 1,275 square feet was developed for studies of bamboo utilization.

A mechanical work shop has been developed for the agricultural engineering division from one of the existing concrete storehouses. This building has been wired for electricity and equipped with both metal and woodworking tools, and now functions not only for the maintenance of experimental farm equipment but also for some of the newly inaugurated projects in agricultural engineering.

A concrete building in serious disrepair was reconditioned by the use of wallboard, paint, and electric wiring. It was made into a small but modern residence for the technical employee in charge of grounds and labor administration.

New patio of tropical design constructed.

The library space of the experiment station is located on the lowest floor of the main office building, two walls of which are well below the adjacent outside ground level. The contour of the terrain abutting on these walls was such that during a long-continued and intense wet season moisture accumulated and seeped into the library. This created a humid atmosphere favorable to the development of molds and unfavorable for the preservation of the books. A concrete cap was placed over the soil abutting against the two walls to collect and discharge the water at a safe distance from the library. A small fountain was placed in the center of this concrete cap which, together with the surrounding walls of the main part of the station building, formed a patio, 20 by 42 feet, of an architectural design well adapted to the tropical setting. This patio has been used several times for informal meetings of the station staff and their families and thus serves a double purpose.

As mentioned previously, a new building was constructed for the experiment station by the F. E. R. A. for the purpose of housing low-temperature and high-temperature equipment furnished and used by the Bureau of Entomology and Plant Quarantine. This house is of reinforced concrete construction and in its total floor space of 465 square feet has two insulated chambers, one of which is used for low-temperature and the other for high-temperature studies.

Under the paragraph describing investigations in plant pathology, mention was made of the construction of a small plant-quarantine house and an insect-proof house for studies of virus diseases of plants.

All construction designed to lessen maintenance costs.

The termite-riddled, decaying wood floors of a large part of the main office and laboratory building were replaced with concrete floors. Similarly the wooden ceilings of all the offices which had become badly termite-infested were taken out and replaced with gypsum board resistant to both termites and rots. Where such construction changes were necessary, the replacements were designed to avoid termite infestation and rotting and reduce to a minimum the cost of future maintenance.

Asphalt and cement were each substituted for dirt floors in one of the stable buildings. Asphalt was used as well as cement to enable observations to be made on the comparative advantages of each type of flooring.

A new boiler for the sterilization of milking equipment was installed in the dairy house. A steam line was run to the outside of the building for use in soil sterilization.

Additional fields prepared for drainage and irrigation.

One of the lowland fields at the experiment station, easily accessible to the main office and laboratory building, has heretofore been waste land because of its swampy, poorly drained condition. During the year a system of surface drains was developed which makes possible the removal of all surface water within 30 minutes after the cessation of any rain. This field was cleared and is now in use for bamboo propagation and insecticidal-plant studies, and the soil has been worked even during the rainy season.

An additional area of approximately 5 acres was made available for crop production during the past dry season by irrigation, in which water was supplied from the adjacent Yaguez River by means of a portable gasoline-driven centrifugal pump.

New dam minimizes freshets and impounds irrigation water.

Several steep-sided, deep valleys, representative of similar valleys throughout the island, exist at the experiment station. In one of these valleys an earth dam was constructed approximately 14 feet in height at the highest point and 60 feet in length. The dam is protected by a concrete spillway and is provided with an irrigation outlet control gate at the bottom of the earth fill. On both sides of the valley, bench terraces and erosion-prevention canals have been prepared which discharge the water accumulating in them behind the dam. The reservoir has a capacity of 3 acre-feet of water, but experience has shown that by raising the overflow outlet another acre-foot can be easily and safely impounded. Construction of the dam cost $300.

It developed during the past rainy reason that the dam could be utilized for freshet control as well as to furnish irrigation water during the dry season. The gates of the irrigation outlet were opened to an extent determined by experience, which permitted a steady manageable flow of water to the lower part of the valley throughout the wet season; during periods of heavy rains, the run-off was confined to the usual flow through the irrigation outlet, while abnormal precipitation was impounded by the excess capacity of the reservoir behind the dam. This objective was not anticipated at the time the dam was constructed but has been a valuable indirect result of impounding the water for irrigation purposes. A picture of the reservoir and dam is shown in figure 9.

Bench terraces constructed to control soil erosion.

In order to check soil erosion, bench terraces were constructed on many of the hillsides on the station property. These hillsides were previously considered nonproductive and the construction of the terraces has not only checked the soil erosion but has increased the area of arable land.

On 1 acre of steep hillside, planted to an orchard crop, contour canals were constructed in order to lessen the volume of run-off water and to decrease its velocity.

Five acres of land were cleared on some of the lesser slopes of the Las Mesas property and mangum terraces were constructed to hold the soil. This terraced field, on what was at one time considered waste land, has been one of the most productive areas of the experiment station during the last 6 months.

The construction of bench and mangum terraces apparently is one of the most direct methods of transferring unemployed man power into capital wealth for the island.

New fencing and roads.

Under tropical humid conditions such as exist at the experiment station in Mayaguez, fence posts are subject to serious rots and termite damage. During the year it has been possible to substitute concrete and steel posts for more than 1,000 feet of old fencing. The reinforced concrete posts are manufactured at the station. The most economical fencing practice has been to place two angle-steel posts for every concrete post.

To minimize houseflies a manure shed was constructed according to designs suggested by the Bureau of Entomology and Plant Quarantine. The shed has a concrete floor with raised sides which will hold a shallow sheet of water. The manure is stacked on a lattice platform and the fly larvae during their development and movements drop from the manure into the water and drown. The sides of the shed are open, but a corrugated-iron roof protects the stack from rain. The storage of manure in this shed has reduced the flies around the stables.

The experiment station maintains approximately 3 kilometers of gravel roads. During the year approximately 500 meters of additional gravel road were constructed on the station farm. Several small sections of this gravel road have been experimentally asphalted or treated with heavy oil in an attempt to reduce maintenance expense.

All of the foregoing construction has been designed and administered by George J. Burkhardt, agricultural engineer, and Charles Pennington, who has had charge of labor administration.

ACTIVITIES OF OTHER AGENCIES OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

Bureau of Plant Industry has made world-wide collection of economic plants for Puerto Rico.

The review of the agricultural work of the year would not be complete without mention of some of the accomplishments of other bureaus and agencies of the Department, with some of which the experiment station is in some small degree of cooperation or at least in frequent contact.

A review has been presented of the work upon insecticidal plants which is being carried on in cooperation with the Bureau of Plant

Industry. Mention has also been made of the large number of plant introductions which are being made into Puerto Rico through the extensive cooperation of the Bureau through its world-wide organization for the collection of economic plant species. These plant introductions required in some cases many years before their value has been demonstrated, but some of the species imported in years past are now beginning to enter into the agricultural activities of the island with increasing importance.

Control of the fruitfly may result in successful new industries.

The Bureau of Entomology and Plant Quarantine has continued its project for the study of the West Indian fruitflies, *Anastrepha* spp., this project being one of its four major projects on tropical fruitflies. This project is important not only for the agriculture of Puerto Rico but also for the agriculture of the Southern States. The building erected by the Federal Emergency Relief Administration has been used to house the fruit-sterilization equipment of the Bureau; records on temperatures which will kill the fruitfly larvae in island fruits are already accumulating. L. C. McAlister, Jr., and J. W. Balock were engaged in these studies of fruitflies and their control.

The experiment station also furnished office and laboratory quarters for R. G. Oakley, the Mayaguez representative of the Bureau, and for 15 investigators engaged on entomological projects under funds provided by the Agricultural Adjustment Administration. These entomologists included M. R. Smith, who was engaged on investigations of the ant-scale-mealybug relationship on coffee and pineapples; H. K. Plank, working upon the rhinoceros beetle and other coconut insects, the pineapple mealybug, and the control of these insects; L. C. Fife, engaged in a survey and life-history studies of the pink bollworm and other cotton insects; H. L. Dozier, working on investigations of screwworms, horn flies and other cattle insects; G. S. Tulloch, engaged on a survey and study of mosquitoes; L. B. Scott, engaged in a study of bean pod borers and onion thrips; and A. H. Madden, engaged in an investigation of the mole cricket and its control.

Bureau of Entomology and Plant Quarantine introduced many important species of beneficial insects.

S. R. Vandenburg, F. M. Wadley, and H. D. Tate were engaged jointly in a study of insect transmission of sugarcane mosaic. B. A. App was engaged in a study of the control of the corn earworm, the corn silk maggot, and the armyworm. K. A. Bartlett was engaged in the receipt and liberation of introduced beneficial insects, natural enemies of insect pests in Puerto Rico. The Bureau with its wide resources of field stations and foreign explorers has obtained and shipped to Puerto Rico a number of species of beneficial insects, parasites, or predators of serious crop insects of the island; of these several species have already been recovered and are apparently successfully established on the island. S. M. Dohanian was engaged in exploration for natural enemies of Puerto Rican insect pests, and in this pursuit spent most of the year in Trinidad, British Guiana, and Peru.

A great step forward was made in the knowledge of Puerto Rican insect pests, and considerable progress was made in their control.

Soil Conservation Service has reversed trend from soil impoverishment to soil reconstruction.

Some of the activities of the Soil Conservation Service were also housed at the experiment station; W. W. Pate, in charge of soil conservation surveys in Puerto Rico, and M. E. Stephens made their headquarters in Mayaguez for a part of the year, as did also A. T. Holman, undertaking the preliminary work for soil-conservation research in the island.

During the latter part of the year a cooperative agreement was completed between the Soil Conservation Service and the experiment station for the development of a program of research and demonstration in soil-conservation projects on the lands of the station. George L. Crawford was appointed to represent the Service in Puerto Rico in connection with this cooperative agreement. Toward the end of the year an agreement was entered into between the station and the Puerto Rico Reconstruction Administration, to place in effect some of the engineering and agronomic practices which have been well established as erosion-control methods. As has been mentioned in the annual reports of the station, soil erosion has been an important factor in the impoverishment of agriculture in Puerto Rico, and the activities of the Soil Conservation Service in the island and active interest and support of the Reconstruction Administration are believed to have been the turning point in changing the course from a continued trend of soil impoverishment to a gradual rehabilitation of the island soils which will be accelerated with time.

Bureau of Chemistry and Soils completed soil survey essential to economic reconstruction.

The Bureau of Chemistry and Soils, as represented by Ray C. Roberts and associates, completed its soil survey at the end of the year. The work was begun in 1932, and the various soils of the island were classified and mapped in detail. A tremendous mass of fundamental information on soils indispensable to the economic reconstruction of the island was developed.

Bureau of Animal Industry has lessened bovine tuberculosis.

The Bureau of Animal Industry has greatly increased the areas which have been accredited as practically free of bovine tuberculosis. Wilbur McPherson has represented the Bureau in this work. The Bureau also inaugurated during the year a campaign of tick eradication in cooperation with the Puerto Rico Reconstruction Administration.

Bureau of Agricultural Economics has improved marketing of island fruits.

The Bureau of Agricultural Economics, represented by A. S. Mason, has continued to maintain its inspection of agricultural products leaving the island, and has initiated improvements in standards, a service that is fundamental to the success of the fruit and vegetable growers of the island.

Forest Service has replanted large areas of the island.

The Forest Service of the Department of Agriculture has an extensive program of reforestation in cooperation with the Insular Department of Agriculture and Commerce and the Puerto Rico Reconstruction Administration; Evan W. Hadley, forest supervisor, is in charge.

This station has been able to be of some small service to the reforestation program by furnishing land for a forestry nursery, and in turn the Forest Service has made available land for quinine planting, as outlined in the previous pages.

Records of Weather Bureau are indispensable to the agriculture of the island.

The Weather Bureau of the Department continues to furnish fundamental statistics which are constantly used by the experiment station in its investigations. The hurricane warnings of the Bureau are now based on such detailed information that they are depended upon and essential to all industrial, marine, and commercial, as well as agricultural, enterprises. R. W. Gray is senior meteorologist in charge.

The experiment station has been able to be of but small service to the Agricultural Adjustment Administration, although contacts are constantly maintained, and some small mutual services have been exchanged. J. B. Frisbie, principal agricultural economist, is in charge.

CHANGES IN PERSONNEL

New work made possible with increased personnel.

The personnel as it existed at the termination of the last fiscal year is still intact, with the addition of several new appointees. The additional appointments were made possible as a result of the allocation of funds from the processing taxes collected in the sale of Puerto Rican sugar.

Charles F. Pennington was appointed specialist in vanilla production on July 1, 1935, and arrived at the experiment station shortly thereafter. Luis A. Gómez was appointed junior scientific aide on July 5, his work to consist largely of agronomic field experiments in sugarcane. On the same date Jorge Rodríguez Iñigo was also appointed as under scientific aide to be engaged in agronomic experiments and breeding of sweet corn. James H. Jensen was appointed plant pathologist and physiologist on July 10 to specialize in sugarcane diseases and agronomy; he undertook his duties at the station on October 4. On July 20 Alfred N. Watson was appointed biometrician and physiologist and arrived at the station shortly thereafter. On the same date Wallace K. Bailey was appointed associate physiologist to specialize in the production of vegetable crops. George J. Burkhardt was appointed associate agricultural engineer on August 26 and arrived at the station September 22. Arthur S. Mason was appointed associate marketing specialist on November 1 to engage in studies of harvesting, packing, shipping, and marketing tropical fruits and vegetables. Rufus H. Moore was appointed assistant plant physiologist on November 11 to undertake studies in the production of insecticidal plant materials. The station staff has also been aided by the appointment of a draftsman, photographer, chief carpenter, garage and truck man, timekeeper, and several laboratory and field aides, whose positions do not appear in the classified list of employees.

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